



THE MONTHLY SKY GUIDE

10th Edition

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Ridpath & Tirion

THE MONTHLY SKY GUIDE • 10th Edition

DOVER

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Illustrated by
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For not in vain we watch the constellations,
Their risings and their settings, not in vain
The fourfold seasons of the balanced year.

Teach me to know the paths of the stars in heaven,
The eclipses of the Sun and the Moon's travails

—Virgil, *The Georgics*

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Introduction

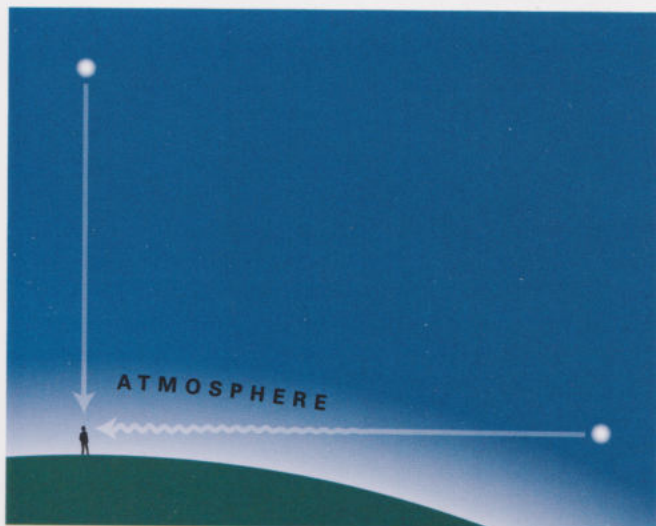
Stars are scattered across the night sky like sequins on velvet. Over 2,000 of them are visible to the unaided eye at any one time under the clearest conditions, but most are faint and insignificant. Only a few hundred stars are bright enough to be prominent to the naked eye, and they are plotted on the monthly sky maps in this book. The brightest stars of all act as signposts to the rest of the sky, as shown on pages 14–15. You only need to know a few dozen stars to find your way around the sky with confidence. This book will introduce you to the stars month by month, without the need for any optical aid, so that you become familiar with the sky throughout the year.

What is a star?

All stars are suns, blazing balls of gas like our own Sun, but so far away that they appear as mere points of light in even the most powerful telescopes. At the center of each star is an immense nuclear reactor, which produces the energy that makes the star shine. Stars can shine uninterrupted for billions of years before they finally fade away.

Many bright stars have noticeable colors—for example, Antares, Betelgeuse, and Aldebaran are reddish-orange. A star's color is a guide to its temperature. Contrary to the everyday experience that blue means cold and red means hot, the bluest stars are the hottest and the reddest stars are the coolest. Red and orange stars have surfaces that are cooler than that of the Sun, which is yellow-white. The hottest stars of all appear blue-white, notably Rigel, Spica, and Vega. On the star charts in this book, the brightest stars are colored as they appear to the unaided eye. Faint stars show no color to the eye at all. Star colors are more distinct when viewed through binoculars or telescopes.

The familiar twinkling of stars has nothing to do with the stars themselves. It is caused by currents of air in the Earth's atmosphere, which produce an effect similar to a heat haze. Stars close to the horizon twinkle the most because we see them through the thickest layer of atmosphere (see *illustration*). Bright stars often flash colorfully from red to blue as they twinkle; these colors are due to the star's light being broken up by the atmosphere.



Twinkling: Stars low down seem to twinkle, because their light passes through more of the Earth's atmosphere than light from stars overhead.

What is a planet?

Eight major planets, including the Earth, orbit the Sun. The basic difference between a star and a planet is that stars give out their own light, but planets do not. Planets shine in the sky because they reflect the light of the Sun. They can consist mostly of rock, like our Earth, or they can be composed of gas and liquid, as Jupiter and Saturn are.

Planets are always on the move, so they cannot be shown on the maps in this book. The two outermost planets, Uranus and Neptune, are too faint to be seen with the naked eye. (Pluto, even fainter and more distant, is no longer regarded as a true planet.) The innermost planet, Mercury, stays so close to the Sun that it is perpetually engulfed in twilight. So there are only four planets that are prominent to the eye in the night sky: Venus, Mars, Jupiter, and Saturn. The positions of these four planets for a five-year period are given in the monthly notes in this book. The planets appear close to the *ecliptic*, the Sun's yearly path around the sky, which is marked as a dashed green line on the maps.

The brightest planet in our sky is Venus, for two reasons: It comes closer to the Earth than any other planet, and it is entirely shrouded by highly reflective clouds. Venus is often called the morning or evening "star," seen shining brilliantly in twilight before the Sun rises or after it has set. As Venus orbits the Sun, it goes through phases like those of the Moon, noticeable through small telescopes and binoculars.

The second-brightest planet as seen from Earth is Jupiter, the largest planet of the Solar System. Binoculars reveal its rounded disk and four brightest moons. Mars, when closest to us, appears as a bright red star, but it is too small to show much detail through small telescopes. Saturn at its closest appears to the eye like a bright star, and binoculars just show the outline of the rings that girdle its equator.

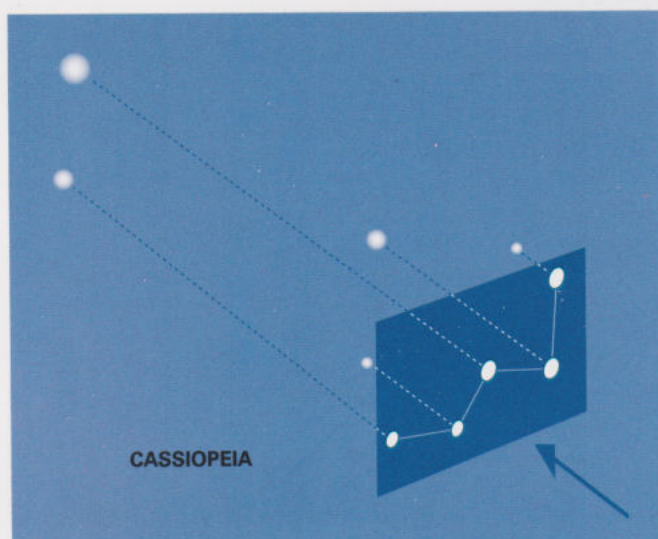
It is often said that planets do not twinkle, but this is not entirely correct. Some twinkling of planets can be seen on unsteady nights, but since planets are not point sources, they twinkle far less than stars do.

What is a constellation?

Over 3,000 years ago, people of the eastern Mediterranean began to divide the sky into easily recognizable patterns, to which they gave the names of their gods, heroes, and fabled animals. Such star patterns are known as constellations. They were useful to seamen for navigation and to farmers who wanted to tell the time of night or the season of the year. By the time of the Greek astronomer Ptolemy in 150 CE, forty-eight constellations were recognized.

Since then, various astronomers have introduced new figures to fill the gaps between the existing ancient constellations. Many of the new groups lie in the far southern part of the sky that was invisible to the Greeks. Some of the newly invented constellations have since been abandoned, others have been amalgamated, and still others have had their names or boundaries changed. This haphazard process has left a total of eighty-eight constellations, of all shapes and sizes, covering the entire sky like pieces of a jigsaw puzzle. They all have Latin names. The constellation names and boundaries are laid down by the International Astronomical Union, the governing body of astronomy.

The stars in a constellation are usually unrelated, lying at widely differing distances from us and each other, so the patterns they form in the sky are entirely accidental. One fact



Constellation: Stars in a constellation lie at different distances from us, as in the case of the five that make up the distinctive "W" shape of Cassiopeia.

that dismays beginners is that few constellations bear any resemblance to the objects they are supposed to represent. Although constellations started out as pictures in the sky, they are now best thought of as a convenient way of locating celestial objects.

How did the stars get their names?

Most bright stars, and several not-so-bright ones, have strange names. Other stars are known by letters and numbers. These designations arose in various ways.

A number of star names date back to Greek and Roman times. For example, the name of the brightest star in the sky, Sirius, comes from the Greek word for sparkling or scorching, in reference to its brilliance. The name of another bright star, Antares, is also Greek. It can be translated as "like Mars" or "rival of Mars"—on account of its strong red color, similar to that of Mars. The brightest star in the constellation Virgo is named Spica, from the Latin, meaning "ear of wheat," which the harvest goddess Virgo is visualized holding.

Most star names are Arabic in origin and were introduced into Europe in the Middle Ages through the Arab conquest of Spain. For example, Aldebaran is Arabic for "the follower," from the fact that it follows the star cluster known as the Pleiades across the sky. Fomalhaut comes from the Arabic, meaning "mouth of the fish," from its position in the constellation Piscis Austrinus, the Southern Fish. Betelgeuse is a corruption of the Arabic *yad al-jawza*, meaning "the hand of Orion." Its name is often mistranslated as "armpit of the central one."

In all, several hundred stars have proper names, but only a few dozen names are commonly used by astronomers. Usually, astronomers refer to stars by their Greek letters, assigned in 1603 by the German astronomer Johann Bayer; hence these designations are known as Bayer letters. Betelgeuse is Alpha (α) Orionis, meaning the star Alpha in the constellation of Orion. Another system of labeling stars is by their numbers in a star catalog compiled by the English astronomer John Flamsteed. These are known as Flamsteed numbers, and they are applied to fainter stars that do not have Bayer letters, such as 61 Cygni. (Note that the genitive, or possessive, case of a constellation's Latin name is always used with Bayer letters and Flamsteed numbers.) Stars too faint to be included in these systems, or stars with particular characteristics, are referred to by the numbers assigned to them in a variety of specialized catalogs.

How far are the stars?

So remote are the stars that their distances are measured not in kilometers or miles but in the time that light takes to travel from them to us. Light has the fastest speed in the Universe, 300,000 km/s (186,000 miles/s). It takes just over 1 second to cross the gap from the Moon to the Earth, 8.3 minutes to reach us from the Sun, and 4.3 years to reach us from the nearest star, Alpha Centauri. Hence Alpha Centauri is said to be 4.3 light years away.

A light year is equivalent to 9.5 trillion km (5.9 trillion miles), so Alpha Centauri is about 40 trillion km (25 trillion miles) away. Even our fastest space probes would take about 80,000 years to get to Alpha Centauri, so there is no hope of exploring the stars just yet.

Most of the stars visible to the naked eye lie from dozens to hundreds of light years away. It is startling to think that the light entering our eyes at night left those stars so long ago. The most distant stars that can be seen by the naked eye are over 1,000 light years away, for example Deneb in the constellation Cygnus and several of the stars in Orion. Only the most luminous stars, those that blaze more brightly than 50,000 Suns, are visible to the naked eye over such vast distances. At the other end of the scale, the feeblest stars emit less than a thousandth of the light of the Sun, and even the closest of them cannot be seen without a telescope.

How bright are the stars?

The stars visible to the naked eye range more than a thousandfold in brightness, from the most brilliant one, Sirius, to those that can only just be glimpsed on the darkest of nights. Astronomers term a star's brightness its *magnitude*. The magnitude system is one of the odder conventions of astronomy.

Naked-eye stars are ranked in six magnitude classes, from first magnitude (the brightest) to sixth magnitude (the faintest). A difference of five magnitudes is defined as equaling a brightness difference of exactly 100 times. Hence a step of one magnitude corresponds to a difference of about 2.5 times in brightness. Two magnitudes correspond to a brightness difference of $2.5 \times 2.5 = 6.3$ times. Three magnitudes equal a brightness difference of $2.5 \times 2.5 \times 2.5 = 16$ times, and so on.

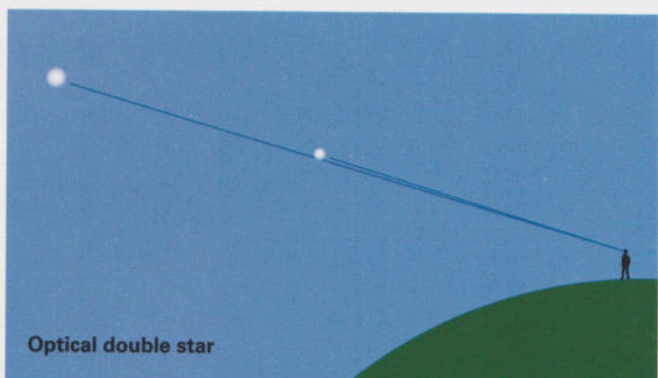
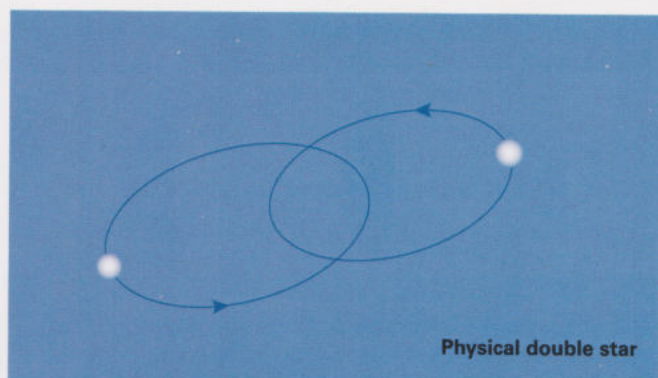
A star 2.5 times brighter than magnitude 1.0 is said to be of magnitude 0 (zero). Objects brighter still are assigned negative magnitudes. Sirius, the brightest star in the entire night sky, has a magnitude of almost -1.5 .

The magnitude system can be extended indefinitely to take account of the brightest and the faintest objects. For instance, the Sun has a magnitude of -27 . Objects fainter than sixth magnitude are classified in succession as seventh magnitude, eighth magnitude, and so on. The faintest objects that can currently be detected by telescopes on Earth are about magnitude 30.

What are double stars?

Most stars are not single, as they appear to the naked eye, but have one or more companion stars. A number of them can be seen through small telescopes and some with binoculars. The visibility of the companion star depends on its brightness and its distance from the primary star—the closer the stars are together, the larger the aperture of telescope that is needed to separate them.

Usually, the members of a star family all lie at the same distance from us and orbit each other as the planets do around the Sun. A pair of stars genuinely related in this way is known as a binary. But sometimes one star simply lies in the background of another, at a considerably greater distance



Double stars: Most double stars are related, and the two stars orbit each other (a physical double, or binary, top). But in some cases, two stars lie by chance in the same line of sight, giving rise to an optical double.

from us (see diagram above). Such a chance alignment of two unrelated stars is called an optical double.

One of the attractions of double and multiple stars is the various combinations of star colors that are possible. For example, one of the most beautiful double stars is Albireo in the constellation Cygnus, which consists of amber and green stars, looking like a celestial traffic light (see page 54). Other impressive double and multiple stars are highlighted in the constellation notes.

What are variable stars?

Not all stars are constant in brightness. Certain stars change noticeably in brightness from night to night, and some even from hour to hour. The brightest of the varying stars is Betelgeuse in Orion, which ranges a full magnitude (i.e., 2.5 times) between maximum and minimum intensity, taking many months or even years to go from one peak to the next. The variations in the light output of Betelgeuse are caused by changes in the actual size of the star. Although the variations of Betelgeuse have no set period, a number of stars pulsate regularly, like a beating heart, every few days or weeks. These are known as *Cepheid variables*, and they follow the rule that the longer the cycle of variation, the more luminous is the star.

Some stars that appear to vary in brightness are actually close pairs in which one star periodically eclipses the other, temporarily blocking off its light from us. The prototype of these so-called *eclipsing binaries* is Algol, in the constellation Perseus, which fades to one-third its usual brightness every 2 days, 20 hours, 49 minutes. This and other interesting variable stars are mentioned in the constellation notes.

The most spectacular of the varying stars are the *novae*, faint stars that can flare up to thousands of times their usual brightness for a few days before sinking back into obscurity. Novae got their name, which is Latin for "new," because in the past they were thought to be new stars appearing in the sky. Now we

know that a nova is actually an old, dim star that has flared up because gas has fallen onto it from a neighbor. Nova outbursts are unpredictable and are often first spotted by amateur astronomers.

What is a shooting star?

During your sky watching, you will from time to time see a bright streak of light dash across the sky like a cosmic laser beam, lasting no more than a second or so. This is a *meteor*, often called a shooting star. Do not misidentify shooting stars as satellites or high-flying aircraft, which look like moving stars but drift at a more leisurely pace.

Despite their name, shooting stars have nothing to do with stars. They are particles of dust shed by comets and are usually no bigger than a grain of sand. They plunge into the Earth's atmosphere at speeds from 10 to 75 km/sec (6 to 46 miles/sec). We see a glowing streak of hot gas as the dust particle burns up by friction with the atmosphere about 100 km (60 miles) above the Earth. The brightest meteors outshine the stars, and some break up into glowing fragments. Occasionally, much larger chunks of rock and metal penetrate the atmosphere and land on Earth. These are called meteorites.

On any clear night, several meteors are visible to the naked eye each hour, burning up at random. These are known as *sporadic meteors*. But at certain times of the year, the Earth plows through dust storms moving along the orbits of comets. We then see a meteor shower, when as many as 100 meteors may be visible each hour.

Because of perspective, all the members of a meteor shower appear to diverge from a small area of the sky known as the *radiant*. The meteor shower is named after the constellation in which its radiant lies: the Perseids appear to radiate from the constellation of Perseus, the Geminids from Gemini, and so on. Meteor showers recur on the same dates each year, although the intensity of a shower can vary from year to year. As the Earth penetrates the swarm of dust, the number of meteors visible each hour builds up over a few days to its maximum and then falls away again. Amateur astronomers monitor the progress of a shower by counting the number of meteors visible and estimating their brightnesses.

When watching for meteors from a shower, do not gaze directly at the radiant. Scan about 45° to the side of it, where the meteor trails will be longest. A list of the year's main meteor showers is given in the table on the next page. Note that the maximum number of meteors quoted will be seen only in dark conditions, when the radiant is high in the sky. If the radiant is low, or if the sky is bright (for instance from moonlight), the number of meteors visible will be much smaller.

What is a comet?

People often confuse comets with shooting stars, but they are quite different. Whereas a shooting star appears as a brief streak of light, a comet looks like a hazy smudge hanging in the sky. A comet's movement against the star background is noticeable only over a period of hours or from night to night. Comets are giant snowballs of frozen gas and dust that move on highly elongated orbits around the Sun, taking from a few years to many thousands of years to complete one circuit.

Dozens of comets are seen by astronomers each year. They are a mix of new discoveries and previously known examples returning to the inner part of the Solar System. Most comets are too faint to be seen without a large telescope. Only rarely, perhaps every ten years or so, does one become bright enough to be prominent to the naked

METEOR SHOWERS

Name of shower	Date of maximum	Number of meteors visible per hour at maximum (approx.)
Quadrantids	January 3–4	100
Lyrids	April 21–22	10
Eta Aquariids	May 5–6	35
Delta Aquariids	July 28–29	20
Perseids	August 12–13	75
Taurids (south)	October 10	10
Orionids	October 21	25
Taurids (north)	November 12	10
Leonids	November 17–18	10
Geminids	December 13–14	100

eye, as Comet Hale–Bopp was in 1997, Comet McNaught in 2007, and Comet Lovejoy in 2011.

A bright comet is absolutely beautiful. From its glowing head, a transparent tail of gas and dust extends for millions of kilometers, always pointing away from the Sun. The dust released by the comet disperses into space, some of it eventually being swept up by the Earth to appear as meteors.

What is an eclipse?

During an eclipse of the Sun, the Moon passes in front of the Sun and cuts off its light from part of the Earth; during an eclipse of the Moon, the Moon enters the Earth's shadow cast in space and hence is darkened. Eclipses occur only occasionally, when the Sun, Moon, and Earth line up suitably. At least two solar eclipses are visible somewhere on Earth every year, and most people will see an eclipse of the Moon every couple of years. Solar and lunar eclipses for a five-year period are listed in the monthly notes in this book. (Note that not every month has an eclipse.)

Solar eclipses are visible from only a limited area on Earth. When the Sun is entirely covered by the Moon the eclipse is said to be total, but a total solar eclipse only lasts a few minutes and is rare from any given point on Earth. A partial solar eclipse can last several hours and is visible over a much wider area.

A special case of a solar eclipse is known as an annular eclipse. This occurs when the Moon is at its farthest from Earth and hence its apparent size is not sufficient to cover the Sun completely—so instead of a total eclipse, a ring of sunlight is left around the Moon. The name annular eclipse comes from the Latin *annulus*, meaning ring.

In contrast to the limited visibility of solar eclipses, eclipses of the Moon can be seen from anywhere on Earth where the Moon is above the horizon. A total lunar eclipse can last over an hour.

What is the Milky Way?

On clear, dark nights, a hazy band of starlight arches across the heavens. The Greeks called it the Milky Way. We know that the Milky Way consists of innumerable stars comprising an enormous wheel-shaped structure, the Galaxy, of which our Sun is a member. The stars that are scattered randomly over the night sky, forming the constellations, are among the nearest to us in the Galaxy. The more distant stars are concentrated into the crowded band of the Milky Way. The Milky Way, therefore, is the rest of our Galaxy as seen from our position within it.

The Galaxy's center lies in the direction of the constellation Sagittarius, where the Milky Way star fields are particularly dense. Our Sun lies approximately two-thirds of

the way from the hub to the rim of the Galaxy, which is about 100,000 light years in diameter. Beyond the edge of the Galaxy is empty space, dotted with other galaxies.

On the monthly star maps, the Milky Way is indicated in a lighter blue. Sparkling star fields spring into view if you sweep along this region with binoculars or small telescopes.

What is a star cluster?

In places, stars congregate in clusters, some of which are visible to the naked eye, most notably the group called the Pleiades in the constellation Taurus. There are two sorts of star clusters, distinguished by the types of stars in them and their location in the Galaxy. *Open clusters* are loose groupings of young stars dotted along the spiral arms of our Galaxy. Some open clusters are still surrounded by the remains of the gas clouds from which they were born. Open clusters can contain from a handful of stars up to a few thousand stars.

Altogether different in nature are the ball-shaped *globular clusters*, mostly found far away from the plane of the Milky Way. They are swarms of up to 300,000 stars, much more tightly bunched than in open clusters. The stars in globular clusters are very old—indeed, they include some of the oldest stars known. Since globular clusters are much farther from us than open clusters, they appear fainter. The best globular cluster for northern observers is M13 in the constellation Hercules (see page 46).

What is a nebula?

Between the stars are vast clouds of gas and dust known as *nebulae*, Latin for mist, a word that accurately describes their foggy appearance. They are best seen in clear country skies, away from smoke and streetlights.

Some nebulae shine brightly, whereas others are dark. The most famous bright nebula is in Orion, visible to the naked eye as a softly glowing patch. The Orion Nebula is a gas cloud from which stars are forming, and the newborn stars at its center light up the surrounding gas (see page 26). Other nebulae remain dark because no stars have yet formed within them. Dark nebulae become visible when they are silhouetted against dense star fields or bright nebulae. The Milky Way star fields in Cygnus are bisected by a major dark nebula, the Cygnus Rift.

Certain nebulae are formed by the deaths of stars, including the so-called *planetary nebulae*, which, despite their name, have nothing to do with planets. The name arose because, when seen through small telescopes, they often look like the disks of planets. Actually, planetary nebulae are glowing shells of gas sloughed off by stars like the Sun at the ends of their lives. Stars that are much more massive than the Sun die in violent explosions, splashing fountains of luminous gas into space. The most famous remnant of an exploded star is the Crab Nebula in the constellation Taurus (see page 70).

What is a galaxy?

Some objects that at first sight resemble nebulae are actually distant systems of stars beyond our Milky Way—other galaxies, many millions of light years apart, dotted like islands throughout the Universe. The smallest galaxies consist of approximately a million stars, while the largest galaxies contain a trillion stars or more. We live in a fair-sized galaxy of at least 100 billion stars known simply as *the Galaxy*.

Galaxies come in two main types: spiral and elliptical. Spiral galaxies have arms consisting of stars and gas winding outward from their star-packed hubs. A subspecies of spiral galaxies, called barred spirals, have a bar of stars across their center; the spiral arms emerge from the ends of the bar. Our

Naming star clusters, nebulae, and galaxies

Star clusters, nebulae, and galaxies are often referred to by numbers with the prefix M or NGC. The M refers to Charles Messier, an eighteenth-century French comet hunter who compiled a list of over 100 fuzzy-looking objects that might be mistaken for comets. Astronomers still use Messier's designations, and enthusiasts avidly track down the objects on his list. In 1888, a far more comprehensive listing of star clusters and nebulous objects was published, called the *New General Catalogue of Nebulae and Clusters of Stars*, or NGC for short. This was followed by two supplements known as the *Index Catalogues* (IC), bringing the total number of objects catalogued to 13,000, most of them only within reach of large telescopes. In this book, we use the Messier numbers where they exist and NGC and IC numbers otherwise.

Galaxy is now thought to be a barred spiral. Elliptical galaxies have no spiral arms. They range in shape from almost spherical to flattened lens shapes.

Time-exposure photographs with large telescopes are needed to bring out the full beauty of galaxies. Through binoculars and small telescopes, most galaxies appear only as hazy patches of light. Like nebulae, galaxies are best seen in clear, dark skies. The nearest major galaxy to us is visible to the naked eye as a faint smudgy patch, similar in apparent width to the full Moon, in the constellation of Andromeda (see page 62); this is known as the Andromeda Galaxy, or M31.

How can I see satellites?

While casually watching the sky, you may see what looks like a moderately bright star drifting along and taking a few minutes to pass from one horizon to the other. This is an artificial satellite, orbiting the Earth a few hundred kilometers up and lit by the Sun. (To confirm that it is not a high-flying aircraft, check with binoculars, which will reveal an aircraft's lights, whereas a satellite will remain a star-like point.) Dozens of satellites are bright enough to be seen by the naked eye, most notably the International Space Station (ISS), which can be dazzling. You may even see ferry craft on their periodic trips to and from the ISS.

Satellites are easiest to see on summer nights, because the Sun doesn't get far below the horizon and satellites are always in daylight. In winter, satellites are visible only shortly after sunset and shortly before sunrise. Sometimes a satellite may fade in or out partway across the sky as it emerges from or vanishes into the Earth's shadow. Some satellites flash as they move, particularly discarded rocket stages that are tumbling in orbit and catch the sunlight as they turn.

Satellite predictions for any location can be obtained from a website called Heavens Above: www.heavens-above.com.

How to look at the stars and planets

To begin stargazing, you need nothing more than your own eyes, supplemented by a modest pair of binoculars. The monthly star charts in this book are designed to be used for stargazing with the naked eye. With these charts, you will be able to identify the stars and constellations visible on any night of the year.

Specific constellations are featured in more detail in the monthly star notes. Studying the objects described in them requires some form of optical aid. Optical instruments collect more light than the naked eye does, thus showing fainter

objects as well as making objects appear bigger by magnifying them. In astronomy, the ability of an instrument to collect light is often more important than the amount by which it magnifies. This is particularly so in the case of binoculars, which are an indispensable starting instrument for any would-be stargazer.

Binoculars usually have relatively low magnifications of between six and ten times, so they will not show detail on the planets, but their light-grasp will bring into view many stars and nebulae that are beyond reach of the naked eye or that are swamped by light pollution in built-up areas. Binoculars have a much wider field of view than telescopes and are better suited for studying extended objects such as scattered star clusters. Even if you subsequently obtain a telescope, binoculars will always be useful.

Binoculars bear markings such as 6×30 , 8×40 , or 10×50 . The first figure is the magnification, and the second figure is the aperture of the front lenses in millimeters: the larger the aperture, the greater the light-grasp and hence the fainter the objects that you can see. Binoculars with high magnifications of 12 times or more are occasionally encountered, but they need to be mounted on a tripod to hold them steady.

Telescopes are rather like telephoto lenses, but whereas a telephoto lens on a camera is described by its focal length, a telescope is described by its aperture. Remember that a telescope with an aperture of, say, 50 mm has the same light-grasp as a pair of 50 mm binoculars, but it can cost several times more. The main advantage of a telescope over binoculars is that it has higher magnification.

The smallest telescopes—those with apertures up to 75 mm (3 inches)—are of the refracting type, like a spyglass, which you look straight through. Larger telescopes, starting with apertures around 100 mm (4 inches), are usually reflectors, in which mirrors collect the light and bounce it into an eyepiece. Reflectors are cheaper to make in large sizes than refractors, and they usually have shorter tubes, which is more convenient.

A third breed of telescope combines lenses and mirrors. These are called catadioptric telescopes and are best thought of as a modified form of reflector. Their main advantage is that they are compact and portable, but they are more expensive than basic reflectors, particularly the so-called GoTo variety that has computer controls for finding objects automatically from a built-in database.

A problem that becomes apparent upon looking through a telescope is the unsteadiness of the atmosphere. Turbulent air currents make the image of a star or planet seem to boil and jump around, which limits the amount of detail that can be discerned, particularly at higher magnifications. The steadiness of the atmosphere is known as the *seeing*, and it changes markedly from night to night. You will be able to see more detail through a telescope on nights with steady air (i.e., good seeing). In addition, the atmosphere dims objects close to the horizon. So whatever you are observing—a star, a planet, or the Moon—always try to choose a time when it is as far above the horizon as possible to reduce the adverse effects of the atmosphere.

Telescopes have interchangeable eyepieces that offer a range of magnifications. High magnifications are useful when studying fine detail on the planets or separating the close components of a double star. But no matter how much magnification you use on a small telescope, it will not show as much detail as a larger telescope. Too high a power on a telescope will make the image so faint that you will end up seeing less than if you had used a lower power. A good rule of thumb is to keep to a maximum magnification of 20 times per 10 mm of aperture (50 times per inch). Do not be tempted by small telescopes that offer magnifying powers of many hundreds of times. In practice, such high magnifications

will be unusable. Most of the objects mentioned in this book are within view of telescopes with an aperture of 100 mm or less, using low to medium magnifying powers.

Finally, be sure to bundle up when going out to observe, even on a mild evening. If you are observing with the naked eye or binoculars, sit in a reclining chair or lie on a sunbed. A comfortable observer sees more than an uncomfortable one.

How to use the maps in this book

There are twelve all-sky charts in this book, one for each month of the year, usable every year. They show the sky as it appears between latitudes 30° north and 60° north at fixed times of night that are convenient for observation. To understand the maps, imagine the night sky as a dome overhead. The maps are a flattened representation of that dome. When you look upward, you must think of the maps as being stuck to the dome of the sky, arching over you on all sides.

To use the maps, turn them so that the direction marked at the bottom of the map—north, south, east, or west—matches the direction you are facing. The map then depicts the sky as it appears at 10 p.m. in mid-month. The sky will look the same at 11 p.m. at the start of the month and 9 p.m. at the end of the month. A table at the bottom of each monthly map shows the times at which the sky appears the same in other months. Note: One hour must be added to these times when daylight saving time is in operation, designated DST in the key. For information on changeover times to DST, see www.webexhibits.org/daylightsaving/b2.html.

If you wish to observe at times other than those in the table, you must make allowance for the changing appearance of the sky caused by the rotation of the Earth, which turns 15° every hour. When your observing time differs by a full two hours from the time shown on a map, you will have to change maps. For every additional two hours' difference, go forward or backward another map as necessary. Inspection of the tables at the bottom of each chart will show that, for example, the appearance of the sky at 10 p.m. in mid-May is the same as at 6 a.m. in mid-January.

You will need to change maps to find when planets are visible if they are located in constellations not above the horizon at 10 p.m. in a given month. For example, if a planet lies in Sagittarius during January, we have to move forward four maps to find the map where Sagittarius first appears above the horizon—the May map. The timetable tells us that Sagittarius, and hence the planet, do not rise until nearly dawn in January.

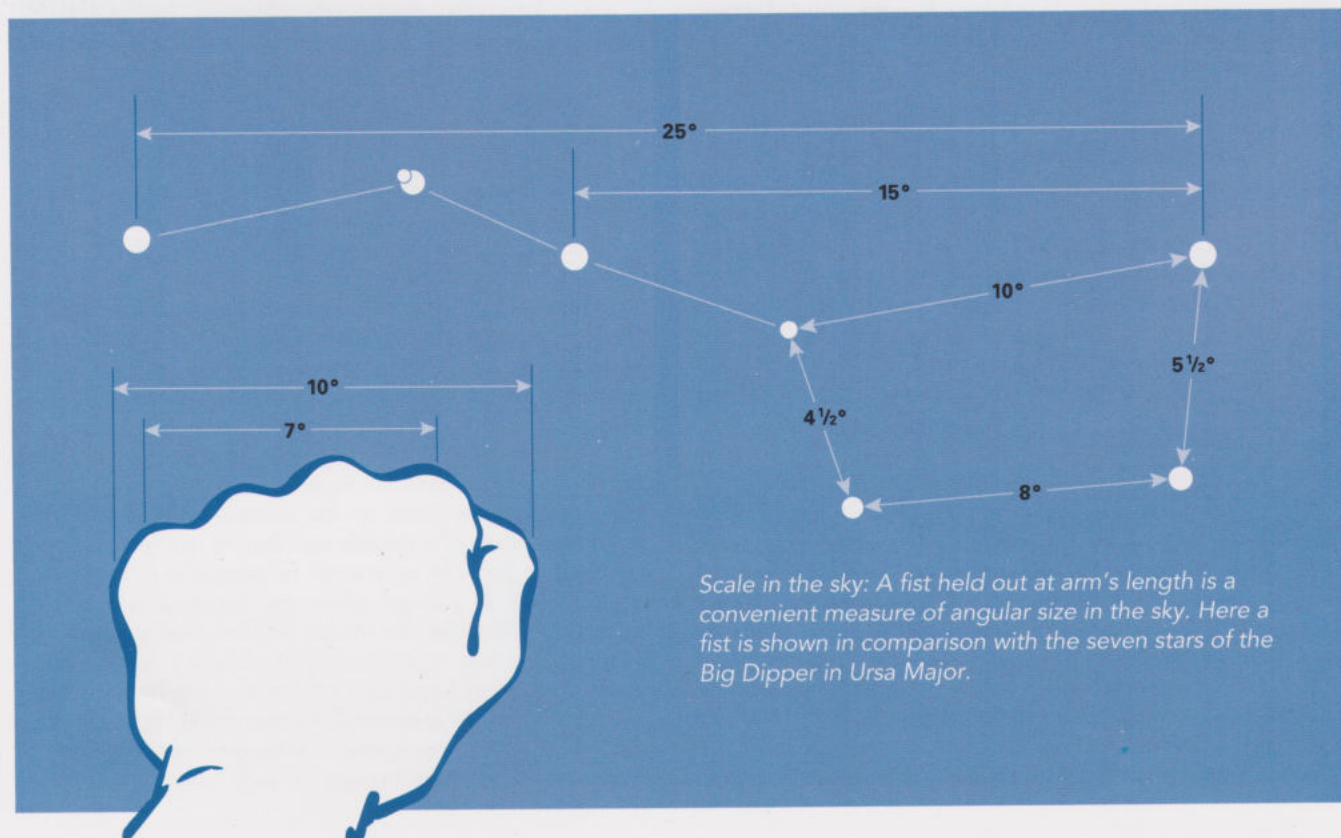
Four horizons are shown on the maps, for observers at latitude 30° north, 40° north, 50° north, and 60° north. It should not be difficult to work out where the horizon falls on the maps for your specific latitude. Note how your latitude affects the stars that are visible. You will be able to use the maps from anywhere between latitudes 30° north and 60° north, and there will be little discrepancy between what the maps show and the way the sky appears for up to 10° outside these limits.

The monthly all-sky maps show the brightest stars down to magnitude 5.0, realistically depicting the sky as seen by the naked eye on an averagely clear night. The maps of individual constellations show stars down to magnitude 6.5, plus fainter selected stars and numerous objects of interest for users of binoculars and small telescopes.

Scale in the sky

One difficulty when matching up the maps in a book with the real sky is scale. Most people overestimate the size of objects in the sky. For example, the full Moon, which is a half-degree across, can be covered by the width of a pencil held at arm's length. (Try it!) An outstretched palm will cover the main stars of Orion, and you can cover most of the stars in the Big Dipper with your hand. An upright hand at arm's length spans about 14° from wrist to fingertips.

How can we judge whether a particular constellation covers a large or small area of sky? The width of a fist held at arm's length makes a convenient distance indicator, about 7° wide. As a guide to scale, each of the constellation maps in this book carries an outline of a fist for comparison. If your hand is unusually big or small the comparison will not be exact, but it will still be a useful guide to the size of the constellation you are looking for.



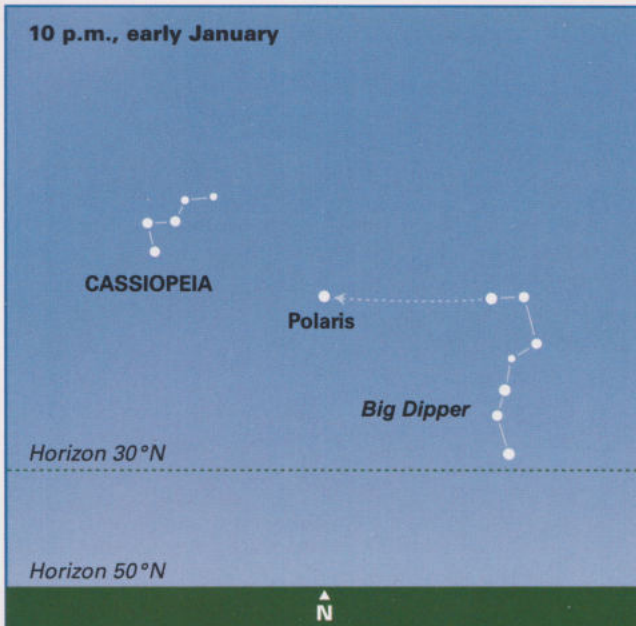
Scale in the sky: A fist held out at arm's length is a convenient measure of angular size in the sky. Here a fist is shown in comparison with the seven stars of the Big Dipper in Ursa Major.

How the sky changes with the seasons

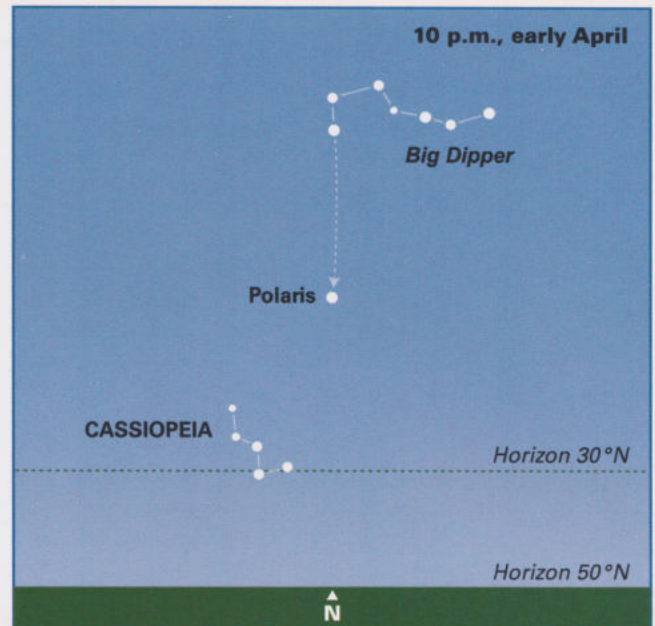
The sky is like a clock and a calendar. It changes in appearance with the time of night and the seasons of the year. For example, look at the diagrams below of the area around the north pole of the sky. At 10 p.m. at the start of the year, the familiar saucer shape of seven stars known as the Big Dipper is standing on its handle to the right of Polaris, the north pole star. At the same time of night three

months later, the Big Dipper is almost directly overhead, while the "W"-shaped constellation of Cassiopeia sits low on the northern horizon. By July, the Big Dipper appears to the left of Polaris. At 10 p.m. in October, the Big Dipper is scraping the northern horizon, while Cassiopeia rides high. In another three months, the stars are back to where they started and the yearly cycle begins anew.

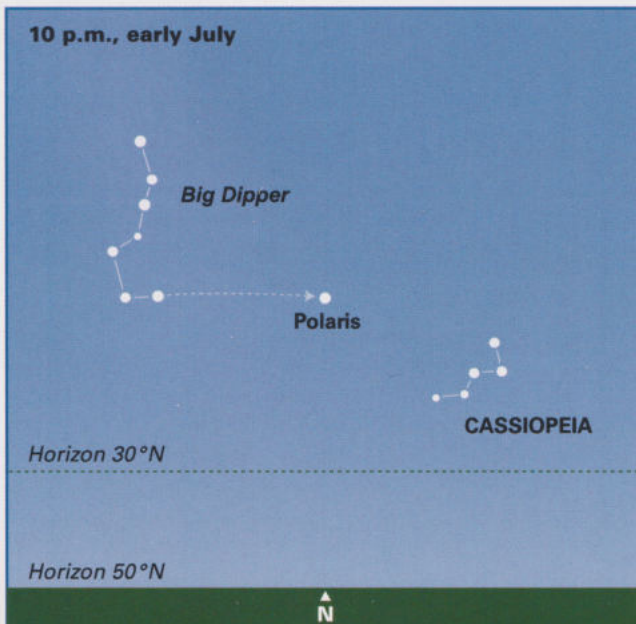
10 p.m., early January



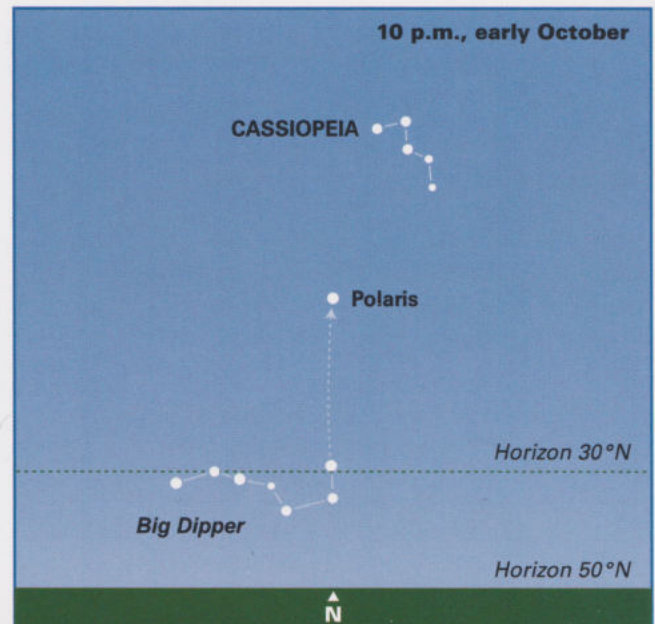
10 p.m., early April



10 p.m., early July



10 p.m., early October



GREEK ALPHABET

α alpha
β beta
γ gamma
δ delta
ε epsilon
ζ zeta

η eta
θ or θ theta
ι iota
κ kappa
λ lambda
μ mu

ν nu
ξ xi
ο omicron
π pi
ρ rho
σ sigma

τ tau
υ upsilon
φ or φ phi
χ chi
ψ psi
ω omega

Finding your way

To find your way in unfamiliar territory, you need a map and signposts. This book provides the maps. The signposts are in the sky. Start with an easily recognizable pattern, such as the Big Dipper in spring or Orion in winter, and work your way outward to locate other constellations and bright stars, a technique known as star-hopping. While star-hopping around the sky, you will find that there are many natural

"pointers" that direct you from constellation to constellation. Also, bright stars often form distinctive patterns of lines, triangles, and squares that you can remember. The four small charts in this section demonstrate some of the best ways of locating prominent stars and constellations in each season. As you navigate your way among the stars, you will discover many more signposts.

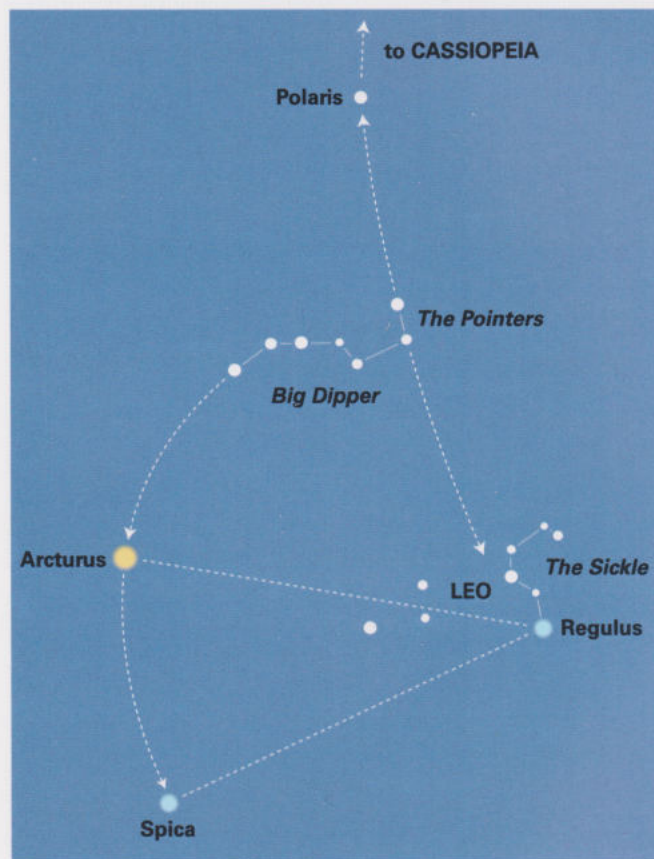
Signposts of spring

Start with the familiar saucepan shape of the **Big Dipper**, which rides high in the sky on spring evenings. The seven stars of the saucepan are actually the most prominent members of the constellation Ursa Major, the Great Bear. From the diagram you can see that two stars of the saucepan's bowl—the ones that lie farthest from the handle—point toward the north pole star, **Polaris**. These two stars in the Big Dipper are known as **The Pointers**. If you extend the distance between them by about five times, you will reach the pole star. Opposite Polaris from the Big Dipper lie five stars that form a distinctive "W" shape, which is the constellation of **Cassiopeia**.

Polaris is a star of moderate brightness lying in a somewhat blank region. It is not exactly at the north pole of the sky but is situated about one degree (two Moon diameters) from it. During the night, the stars circle around the north celestial pole (and hence around Polaris) as the Earth spins on its axis.

Go back to the Big Dipper. If you extend the Pointers in the opposite direction, away from Polaris, you will come to the constellation of **Leo**, the Lion. This constellation is notable for the sickle shape of stars, like a reversed question mark, that makes up the lion's head.

Now look at the handle of the Big Dipper. Follow the curve made by the stars of the handle until you come to **Arcturus**, one of the brightest stars in the sky. Continue the curve and you reach the sparkling star **Spica**, in the constellation of Virgo. Note that Arcturus and Spica form a prominent triangle with **Regulus**, the brightest star in Leo.

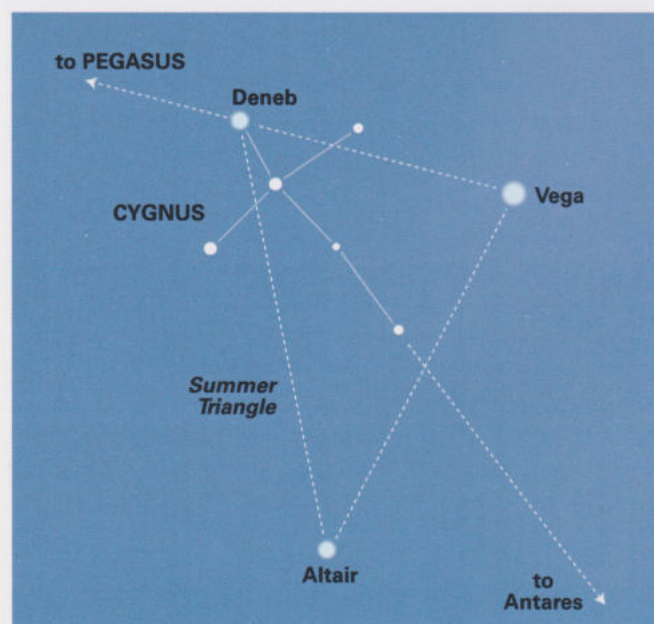


Signposts of summer

High in the sky on summer evenings lies an isosceles-shaped trio of bright stars known as the **Summer Triangle**. In order of decreasing brightness they are **Vega**, **Altair**, and **Deneb**. Vega is the first star to appear as the sky darkens in July and August, shining overhead like a blue-white diamond.

Deneb is the brightest star in **Cygnus**, a constellation that represents a swan but is better visualized as a cross, as shown on the diagram here. Deneb marks the head of the cross. The foot of the cross bisects a line between Vega and Altair and points toward the bright star **Antares**, which appears low on the horizon from mid-northern latitudes. Antares lies due south as the sky darkens in July. It has a prominent red color and represents the heart of the Scorpion, Scorpius.

A line from Vega through Deneb directs you toward the **Square of Pegasus**, a quadrangle of four stars that is the centerpiece of the autumn sky. Apart from the Summer Triangle, the summer sky is remarkably bereft of prominent star patterns. Incidentally, despite its name, the Summer Triangle remains visible well into the autumn. A better name would be Northern Triangle.



Signposts of autumn

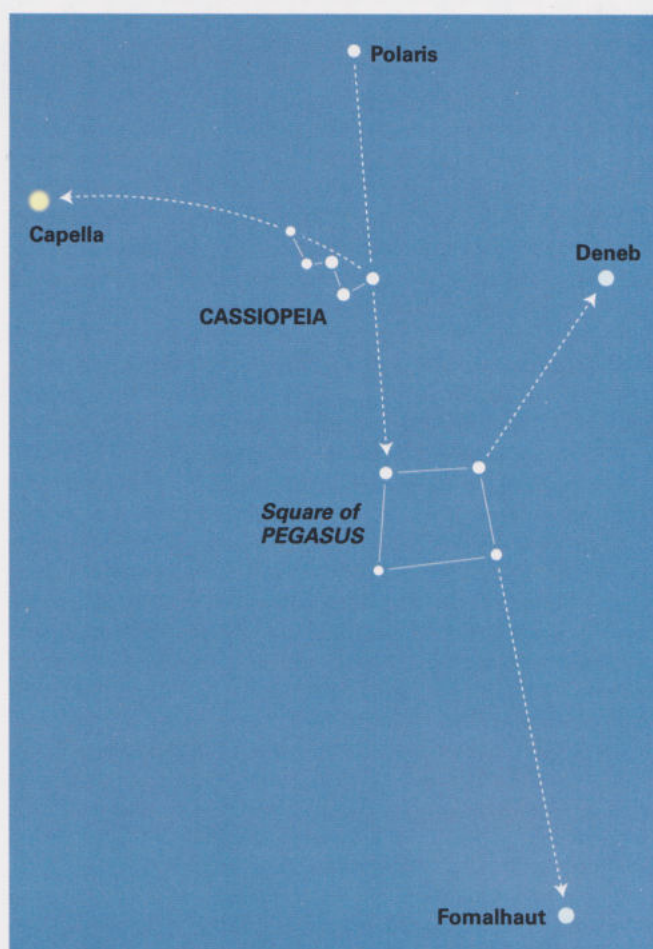
As the Summer Triangle sets in the west on autumn evenings, the **Square of Pegasus** takes center stage. The Square lies high in the south at 10 p.m. in mid-October, 8 p.m. in mid-November, and 6 p.m. in mid-December. The four stars that mark the corners of the Square are of moderate brightness, similar to the stars of the Big Dipper. They enclose a large area of the sky that is almost entirely devoid of naked-eye stars. In fact, the Square is so large that a line of more than thirty full Moons could fit side-by-side across it.

The Square of Pegasus is like a keystone in the autumn sky, from which many surrounding stars and constellations can be identified. To the top right of the Square lie departing **Deneb** and the rest of the Summer Triangle.

Between the Square and the pole star lies the "W"-shaped constellation of **Cassiopeia**. As the diagram at the right demonstrates, a line extended upward from the left-hand side of the Square passes through the end of Cassiopeia's "W" and on to **Polaris**, the north pole star. Alternatively, you can use this line in reverse, running it from Polaris through Cassiopeia, to find the Great Square.

A line extended downward from the right-hand side of the Square directs you to **Fomalhaut**, a bright star in the southern constellation of Piscis Austrinus. It's often difficult to find from mid-northern latitudes because it is so close to the horizon.

Now look at Cassiopeia, riding high above you. A line drawn across the top of the "W" and away from Cygnus points to **Capella** in the constellation Auriga, one of the prominent stars of the winter sky.



Signposts of winter

The sky is more richly stocked with bright stars in winter than in any other season. The jewel in winter's crown is the brightest star in the night sky, **Sirius**, which glitters due south at midnight at the beginning of January. As with all stars, it arrives back at the same place in the sky about two hours earlier every month. At the beginning of February it is due south at 10 p.m., and it is due south at 8 p.m. by the beginning of March. Sirius lies at the southern apex of the **Winter Triangle** of brilliant stars, which is completed by **Procyon** to its upper left and **Betelgeuse** to its upper right.

Betelgeuse marks the top left of the constellation of **Orion**, a rectangular figure that is the easiest of the winter constellations to recognize. At the bottom right of Orion's rectangle is **Rigel**, a star slightly brighter than Betelgeuse. Two fainter stars complete the rectangle. Across the center of Orion runs a distinctive line of three stars comprising **Orion's belt**.

To the top right of Orion is another prominent star, **Aldebaran**, which represents the glinting eye of Taurus, the Bull. Aldebaran is of similar brightness to Betelgeuse, and both stars have a noticeably orange tinge, whereas Rigel is bluer. Continue the line from Orion through Aldebaran and you will come to a hazy-looking knot of stars called the **Pleiades**, a star cluster that shows up well in binoculars.

Above Orion, almost directly between it and the north celestial pole, lies the bright star **Capella** in the constellation Auriga, the charioteer. To the top left of Orion, above the Winter Triangle, lies a famous pair of stars called **Castor** and **Pollux**, the celestial twins in the constellation Gemini. Off to the left of Castor, Pollux, and Procyon lies **Leo**, the Lion, which introduces us once again to the skies of spring.



Observing the planets

Four planets are easily visible to the unaided eye: Venus, Mars, Jupiter, and Saturn. Mercury, the innermost planet, may be glimpsed from time to time in the evening or morning twilight, but it's usually too close to the Sun to be easily seen. Uranus and Neptune, the planets beyond Saturn, are too faint to see without some form of optical aid and even then appear as little more than points of light.

Where and when can I see the planets?

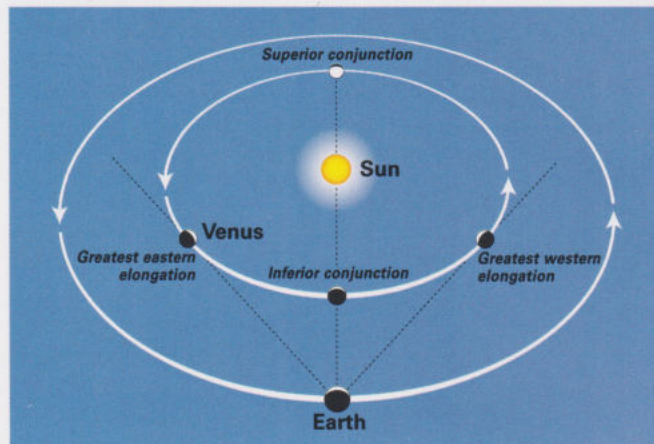
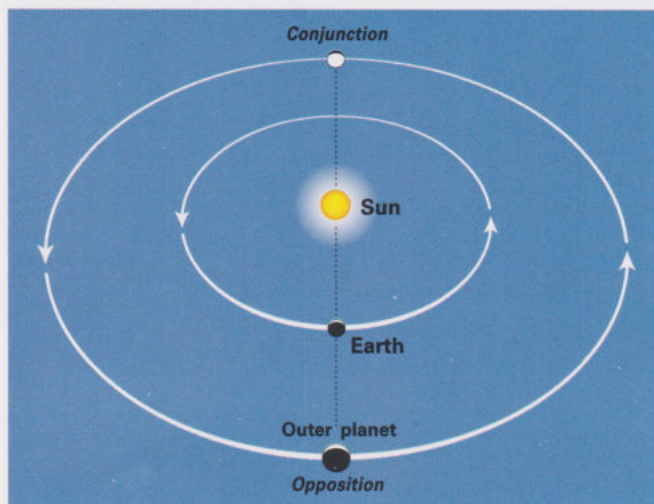
Planets move around the Sun in an orderly fashion, although it might not seem so as viewed from Earth. A planet's orbital period is inextricably linked to its distance from the Sun, as decreed by the laws of celestial motion. The more distant the planet, the longer it takes to complete one circuit. Venus, closer to the Sun than the Earth, completes one trip around the Sun in about seven and a half of our months, shining brilliantly in the evening and morning sky in turn. Being so startlingly bright and reaching magnitude -4.7 at best, it is sometimes reported as a hovering UFO.

Twice on each orbital circuit, Venus reaches a maximum angular separation from the Sun, its *greatest elongation*, once in the morning sky and once in the evening sky. At greatest elongation, Venus lies between 45° and 47° from the Sun and appears half illuminated through a telescope.

There are two other cardinal points that Venus reaches on each orbit: *superior conjunction*, when it is on the far side of the Sun from us and unobservable, and *inferior conjunction*, when it lies between Earth and the Sun and is also unobservable (see diagram above right). Venus normally passes above or below the disk of the Sun at inferior conjunction, because its orbit is not quite in the same plane as ours. Very rarely, the lineup is exact and then it can be seen in silhouette as a black dot crossing the Sun's face, an event known as a *transit*. The transit of Venus in June 2012 was the last until December 2117.

Mars, Jupiter, and Saturn are all farther from the Sun than we are and take longer to complete a circuit: nearly two years for Mars, nearly twelve years for Jupiter, and over twenty-nine years for Saturn. Being exterior to the Earth's orbit, these

Opposition and conjunction: The two cardinal points in the orbits of the outer planets are opposition, when they are closest to Earth, and conjunction, when they are on the far side of the Sun and invisible.



Elongations and conjunctions: Venus reaches its greatest angular separation from the Sun, its greatest elongation, twice on each orbit. At inferior and superior conjunctions, it is in line with the Sun and invisible.

planets can appear opposite the Sun in our sky, a circumstance known as *opposition*. At such times, the planets lie due south around midnight and are visible all night. Opposition is the best time to observe the outer planets because they are closest to the Earth and appear at their biggest and brightest.

What can I see of Venus?

Although Venus is the easiest planet to identify because of its extreme brilliance, it does not give up many secrets when viewed through a telescope because unbroken clouds completely veil its surface. Most obvious is the changing phase as it orbits the Sun, similar to the phases of the Moon (see diagram below). When it appears as a crescent, Venus is on the near side of its orbit to us and is large enough for the phase to be seen through binoculars.

Through small telescopes, a few smudgy markings can be made out in the clouds of Venus. In particular, the polar regions can appear brighter than the rest of the planet, due to the circulation of the clouds from the equator to the poles. The dividing line between the dark and light sides, called the *terminator*, often appears irregular because of shadings in the clouds. Venus is so bright that it is best observed against a twilight sky; otherwise, it dazzles the eye and all detail is lost.

Although Venus is virtually the same size as the Earth, the two planets have evolved very differently. Underneath its clouds, Venus is a roastingly hot world of lava plains and volcanic mountains, more akin to hell than heaven.

Phase change: Venus shows a full phase when at superior conjunction (it is then on the far side of the Sun and cannot be observed), a half phase when it is at greatest elongation (maximum separation from the Sun), and a crescent phase when it is near the Earth and at its brightest.



What can I see of Mars?

Mars, a rocky body about half the size of the Earth, is commonly known as the red planet because of its distinctive color, a result of the red deserts that comprise most of its surface. Mars reaches opposition every twenty-six months, but because its orbit is markedly elliptical, its distance from us at opposition can range from less than 60 million kilometers to 100 million kilometers or more. At a close opposition, a magnification of 80 times makes Mars look as large as the full Moon, but at a distant opposition a magnification of 130 times is needed. Close oppositions of Mars occur at intervals of fifteen or seventeen years, when its brightness rivals that of Jupiter, which is normally the second-brightest planet. But away from opposition, Mars fades to look like an ordinary star.

When Mars is favorably placed, various surface markings can be discerned through a small telescope. Most prominent of these is a dark, wedge-shaped feature called Syrtis Major, an area of darker rock, south of which is a circular, lighter-colored impact basin called Hellas. These, and other markings, come and go from view as the planet rotates every 24.6 hours, only slightly longer than the length of the day on Earth. Also easily seen are the white polar caps, composed of frozen water and carbon dioxide, which alternately grow and shrink with the changing seasons. Larger telescopes may show wispy clouds in the planet's thin atmosphere, while occasional dust storms can obscure part or even all of the surface for days or weeks.

What can I see of Jupiter?

Jupiter is the largest of the planets, more than eleven times the diameter of the Earth, and the favorite of most beginners to planetary observing. Ordinary binoculars will show its rounded outline, and even the simplest telescope will pick out the most prominent of the dark bands that cross its cloudy surface. Unlike the small, rocky inner planets, giant Jupiter and the large planets beyond it are composed mostly of hydrogen and helium, although in their interiors it is compressed into a liquid rather than a gas.

Jupiter comes to opposition every thirteen months, when it can shine at up to magnitude -2.9 , far brighter than any star and second only to Venus. At opposition, a magnification of around 40 times will make the planet appear as large as the full Moon does to the naked eye. In fact, Jupiter displays the largest disk of any of the planets, apart from Venus when it is a crescent.

Jupiter is enveloped in colorful clouds, which are in a perpetual state of flux. That is what makes the planet so fascinating to observers. The only near-permanent feature is the Great Red Spot, an oval-shaped storm cloud in the planet's southern hemisphere several times larger than the Earth. Like all the other features of Jupiter's clouds, the Red Spot is carried in and out of sight as the planet rotates in just under ten hours, the fastest spin of any of the planets in our Solar System. From time to time, new dark and bright spots break out, lasting for weeks or years, while the various cloud bands undergo long-term changes in intensity, color, and structure.

Adding to the interest of observing Jupiter, its four brightest moons, Io, Europa, Ganymede, and Callisto, present an ever-changing arrangement as they orbit the planet. Even simple binoculars, held steadily, will show them as points of light on either side of the planet. Do not expect to see all four every time you look; sometimes one or more is lost behind Jupiter, eclipsed by its shadow, or crossing in front of it.

Ganymede is the largest moon in the Solar System, 5,262 km (3,270 miles) in diameter. Callisto and Io are also larger than our Moon, and Europa is not much smaller. Collectively, the quartet are known as the Galilean satellites, because they were discovered by the Italian scientist Galileo Galilei in 1610.

What can I see of Saturn?

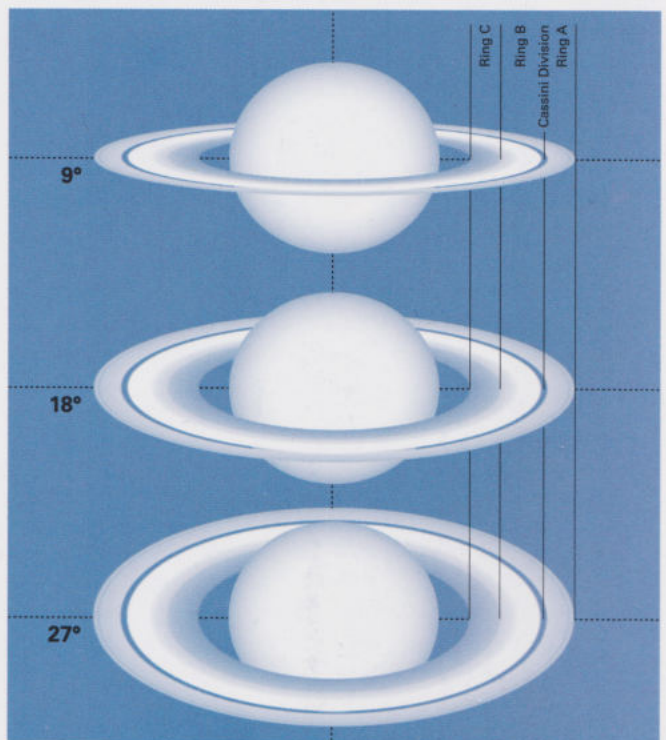
Undoubtedly the most beautiful planet as seen through a telescope is Saturn, girded by its bright rings. Saturn comes to opposition about two weeks later each year, when it appears as a yellowish first-magnitude star. At opposition, a magnification of about 90 times will enlarge the globe of Saturn to the same size as our Moon appears to the naked eye. Note that the body of Saturn appears squashed—its polar diameter is 10 percent less than at the equator. Saturn is a smaller version of Jupiter, but with a far less stormy atmosphere.

Small telescopes show little more than a few hazy bands of cloud and darker polar regions. Inevitably, the magnificent rings steal the attention. Although they may look solid, the rings are composed of countless icy moonlets orbiting the planet's equator. There are three main sections to the rings. The brightest section, and also the widest, is the central one, Ring B. This is separated from the outer Ring A by a gap the width of the northern Atlantic Ocean called the Cassini Division, visible through a small telescope as a dark ribbon. Closer to the planet than Ring B is the faintest section, Ring C, also known as the crepe ring because it is semitransparent and the body of the planet can be seen through it.

The rings throw their shadow onto the cloud tops of Saturn, creating the impression of a dark equatorial band, while the planet casts its own shadow onto the rings behind it. You should also be able to see Saturn's largest moon, Titan, orbiting the planet like a 9th magnitude star every sixteen days. With a diameter of 5,150 km (3,200 miles), Titan is the second-largest moon in the Solar System and the only one with a substantial atmosphere.

As Saturn moves around the Sun, we see the rings from a range of angles. At their widest they can be tilted toward us at 27° , while at other times they are seen edge-on and disappear altogether. The changing presentation of the rings affects the apparent brightness of Saturn in the night sky as well as its appearance through a telescope. Without its rings, Saturn would be less than half as bright.

Ringing the changes: Saturn's rings seen at three different angles of display: 9° , 18° , and 27° (the maximum tilt as visible from Earth).



Observing the Moon

The Moon is the most familiar object in the night sky. A quarter the diameter of the Earth, it is our nearest neighbor, 384,400 km (239,000 miles) away, close enough that surface features can be seen with the human eye. Light and dark areas form a shape like a lopsided face, the "Man in the Moon."

Binoculars and small telescopes bring a wealth of detail into view, as shown on the maps on the following pages. The bright areas are seen to be rugged uplands, while the dark areas are lowland plains, called *maria* (singular: *mare*), Latin for "seas." This name arose because early astronomers thought that they were areas of water, although we now know that the Moon is both airless and waterless. Craters are scattered everywhere, particularly in the highlands.

Imaginative names are given to the various mare areas, such as Mare Tranquillitatis, the Sea of Tranquility, where the Apollo 11 astronauts landed in 1969, and Mare Serenitatis, the Sea of Serenity. Look in particular at Mare Imbrium, the Sea of Rains, over 1,000 km (600 miles) across; on its northwest shore lies the semicircular Sinus Iridum, the Bay of Rainbows, which stands out beautifully when caught by low sunlight. The largest mare area is actually called an ocean—the irregular Oceanus Procellarum, the Ocean of Storms.

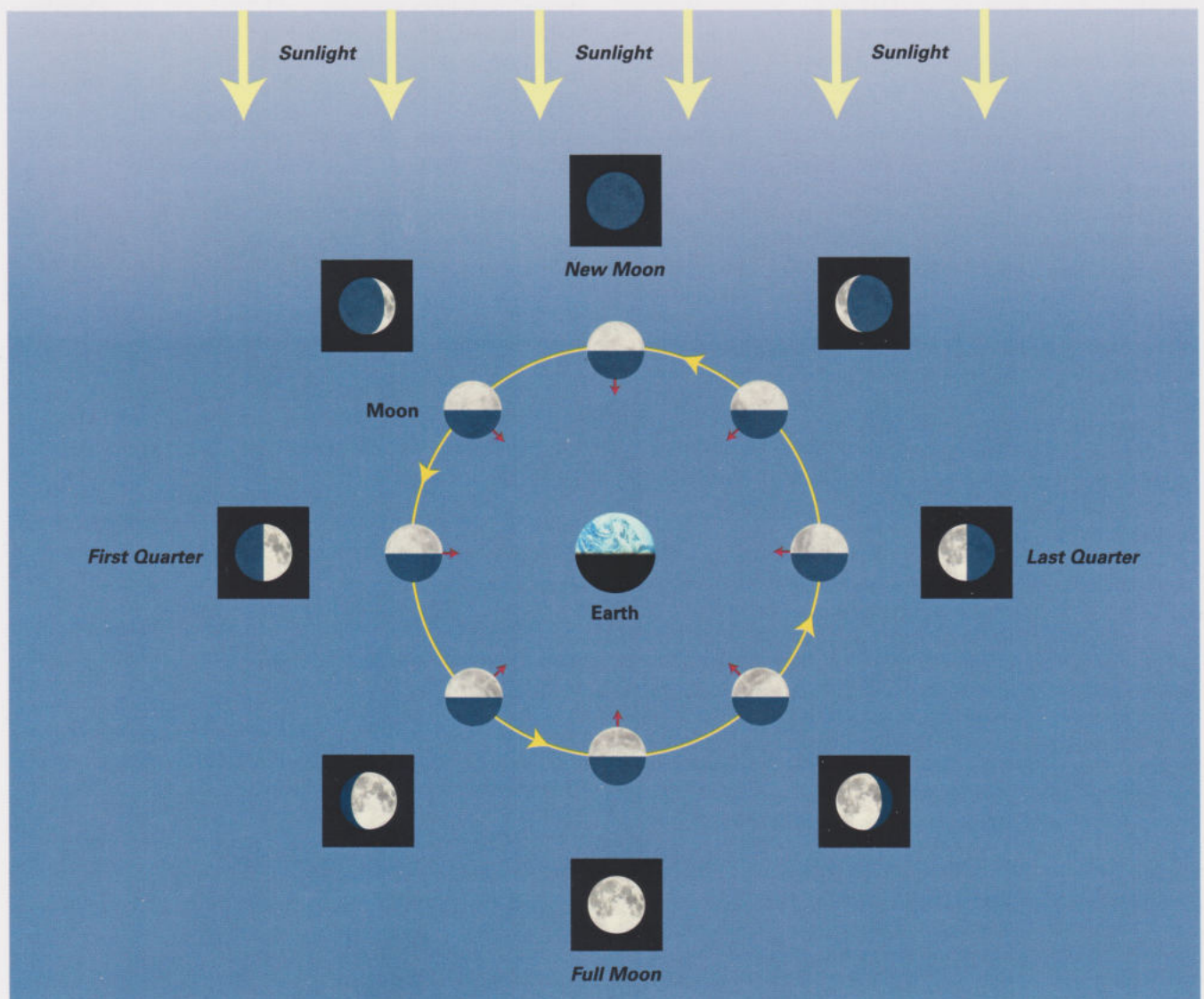
Whenever we look at the Moon, we always see the same surface features. This is because the Moon's rotation has been locked by the gravitational pull of the Earth so that it turns to keep the same side facing us. The far side of the Moon has been seen only on photographs and by a few lucky astronauts.

Why does the Moon change shape?

As the Moon orbits the Earth, it undergoes a monthly metamorphosis. These changes in shape are known as the phases of the Moon. A complete cycle of phases takes 29.5 days, the origin of our time period called the month.

The phases arise from changing solar illumination. Half the Moon is always sunlit, but during its monthly trip around the Earth, we see differing amounts of that sunlit side (see diagram below). When the Moon lies in the same direction as

Phases of the Moon: Starting as a slender crescent in the evening sky after sunset, the Moon's phase grows from night to night, from a half Moon to a fully rounded disk. After full Moon it shrinks again, ending as a thin crescent in the early morning sky before sunrise. In step with its orbital motion, the Moon turns on its axis to keep the same side facing us.



the Sun, all of the sunlit side is turned away from us and the Moon is said to be “new.” As the Moon embarks on another orbit around the Earth, we see progressively more of its sunlit side: first a crescent, then a half Moon (called *first quarter*), then a three-quarter Moon (called *gibbous*), and finally a full Moon, when the Moon is on the opposite side of the Earth from the Sun. While the phase is increasing, the Moon is said to be *waxing*. After a full Moon, the phases run in reverse, back to new Moon; during this second half of the cycle, the Moon is said to be *waning*.

What can I see on the Moon?

Along the boundary between the sunlit and unlit parts of the Moon, the *terminator*, shadows are long and mountains and craters are thrown into sharp relief. From night to night, as the terminator marches across the surface and the Sun climbs higher in the lunar sky, shadows shorten and surface relief becomes progressively less noticeable. At the same time, differences in contrast become more pronounced, such as the bright rays surrounding some of the more prominent craters (see *photographs below*). The appearance of a given area on the Moon can change radically depending on whether it is near the terminator. Craters appear particularly cavernous when they are close to the terminator and their interiors are filled with shadows.

Features to look out for in large lunar craters are central peaks, caused by rebound of the underlying layers following the impact that formed them, and terraced walls, caused by slumping. The largest craters have been flooded by lava, leaving them with flat floors; such formations are sometimes called *walled plains*.

Around relatively young craters such as Copernicus, diameter 93 km (58 miles), and Tycho, diameter 85 km (53 miles), the pulverized rock ejected when they were formed can still be seen. In the case of Tycho, tentacle-like rays of bright ejecta extend up to about 1,500 km (1,000 miles) across the lunar surface.

Under low angles of illumination, the mare surfaces look as though they are puckered in places. These low *wrinkle ridges* arose when the lava that formed the maria cooled. Prominent examples are seen in Mare Serenitatis, Mare Imbrium, and Mare Tranquillitatis.

Which way is up?

Lunar charts are usually drawn with north at the top, such as those on the following pages; this is the view that you will see with the naked eye and through binoculars. But

Trick of the light: The crater Copernicus and its surroundings when close to the terminator (left) and at full Moon. (Consolidated Lunar Atlas)



Views of the Moon: Above, the Moon as seen with the naked eye or through binoculars; north is at the top. Top right, the Moon as seen through an astronomical telescope; the image has been turned through 180° so that north is at the bottom. Right, the Moon as seen through a telescope with a 90° star diagonal; north is at the top but left and right are reversed.



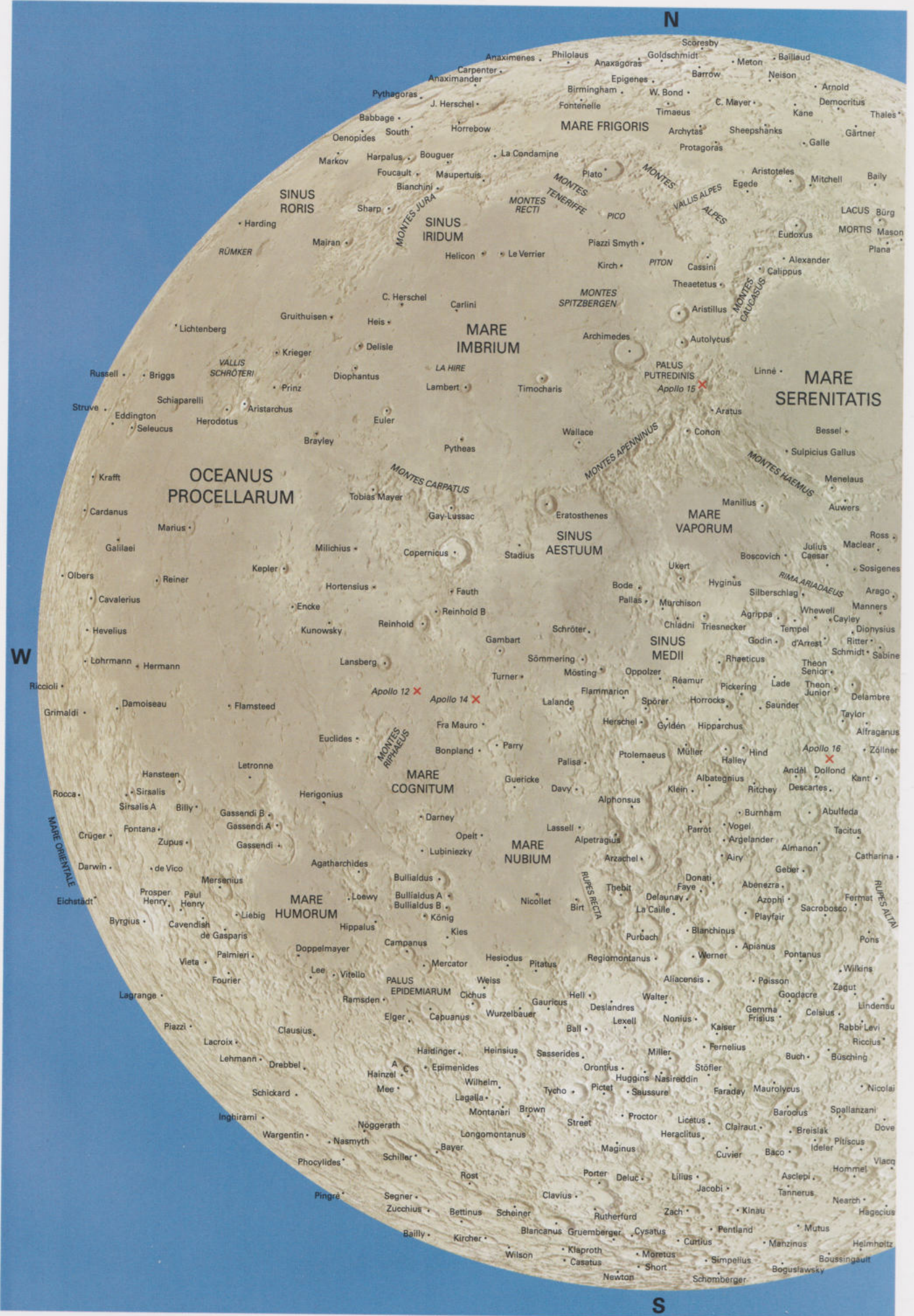
astronomical telescopes produce an inverted (upside-down) image. For stellar subjects, an inverted image makes little difference, but when you are locating features on the Moon, you will have to turn the charts upside-down to match the telescopic view. Some telescopes come equipped with a device called a *star diagonal*, in which a small mirror reflects the light exiting the telescope through 90° for a more comfortable viewing position. This returns the image to an upright position but leaves it reversed left to right, which can be more disorienting than a simple north-south inversion.

What caused the Moon's features?

Heavy bombardment by debris from space has sculpted the lunar landscape that we see today. Early in its history the Moon was hit by a salvo of stray asteroids that dug out the lowland basins. Over the next few hundred million years, lava from inside the Moon flooded these basins, creating the dark maria. This process came to an end around 3 billion years ago. Since then, meteorites have continued to pepper the Moon, the largest of them digging out prominent craters, such as Copernicus and Tycho. Copernicus is estimated to have been formed about 800 million years ago and Tycho about 100 million years ago, so even though they are among the youngest major formations on the Moon, they are still incredibly old on the human timescale.

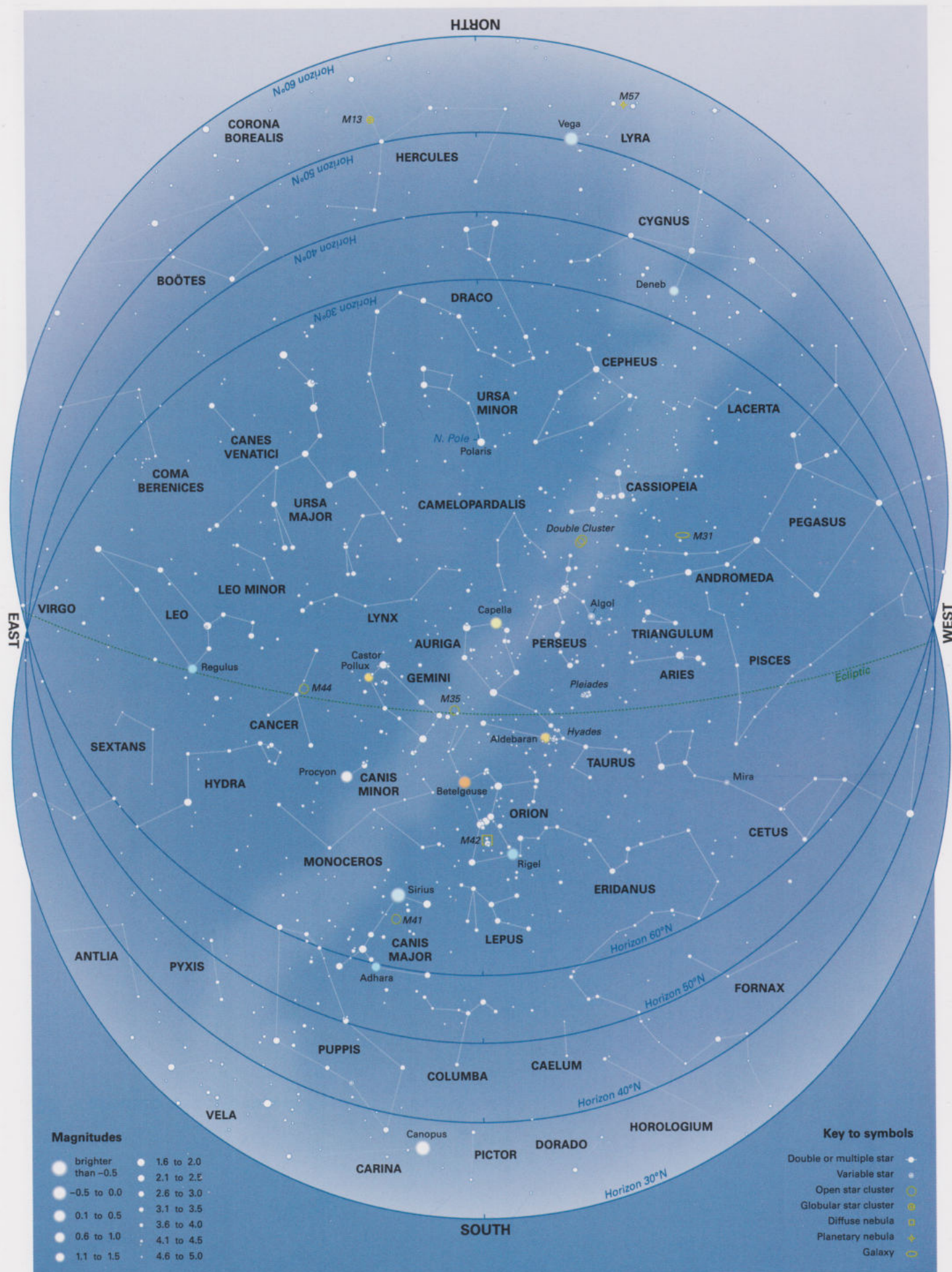












Date	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY
Time	4 a.m.	3 a.m.	2 a.m.	1 a.m.	midnight
DST	5 a.m.	4 a.m.	3 a.m.	2 a.m.	1 a.m.

January

KEY STARS

Sirius, the jewel of the winter sky, glitters brilliantly in the south this month. It lies low in the sky for observers in high northern latitudes and often appears to flash a multitude of colors as its light is refracted by the atmosphere. Sirius forms one vertex of the Winter Triangle of three bright stars, completed by red Betelgeuse to its upper right and white Procyon above and to its left. Capella appears directly overhead this month at 10 p.m. from mid-northern latitudes. Observers below latitude 37° north will find Canopus due south at 10 p.m., beneath Sirius. (Canopus is below the horizon from more northerly latitudes.)

The planets this month

Venus

- 2020 A brilliant object in the southwestern evening sky after sunset at mag. -4.0.
- 2021 In the dawn sky, but too close to the Sun for observation.
- 2022 Unobservable in the first half of the month as it moves behind the Sun (at superior conjunction on January 9) but emerges into the southeastern dawn sky at mag. -4.6 by month's end.
- 2023 Emerges into the southwestern evening sky during the month at mag. -3.9, but remains low as seen from more northerly latitudes. Passes less than one Moon diameter from fainter Saturn (mag. 0.8) on January 22.
- 2024 In the southeastern evening sky at mag. -4.0, becoming engulfed in evening twilight by the end of the month for more northerly observers.

Mars

- 2020 Low in the southeastern dawn sky at mag. 1.5, becoming lost in twilight by month's end from more northerly latitudes.
- 2021 In the southwestern evening sky, passing from Pisces into Aries at the start of the month, and fading from mag. -0.2 to +0.4.
- 2022 Low in the southeastern dawn twilight at mag. 1.5 as seen from mid-northern latitudes and below, but too low for observation from farther north. Lies to the right of brilliant Venus at month's end.
- 2023 An evening object in Taurus, almost stationary north of the Hyades star cluster, fading from mag. -1.2 to -0.3 during the month.
- 2024 Low in the southeastern dawn sky at mag. 1.4 as seen from more southerly latitudes, but too low for observation from mid-northern latitudes and above. Passes less than one Moon diameter from brighter Mercury (mag. -0.2) on January 27-28.

Jupiter

- 2020 Emerges into the southeastern dawn sky during the month at mag. -1.9 as seen from more southerly latitudes, but remains too low for observation from mid-northern and northern latitudes.
- 2021 Too close to the Sun for observation throughout the month. At conjunction (behind the Sun) on January 29.
- 2022 In the southwestern evening sky after sunset at mag. -2.1, but becoming lost in twilight by month's end.
- 2023 An evening object in southern Pisces at mag. -2.3.

- 2024 Prominent all evening and until after midnight in Aries at mag. -2.5.

Saturn

- 2020 At conjunction (behind the Sun) on January 13 and unobservable throughout the month.
- 2021 At conjunction (behind the Sun) on January 24 and unobservable throughout the month.
- 2022 Rapidly becomes lost in evening twilight as it moves behind the Sun toward conjunction next month.
- 2023 Low in the southwest sky after sunset at mag. 0.8, becoming lost in evening twilight during the month as it moves behind the Sun. Rings tilted Earthward at 13°.
- 2024 Low in the southwestern evening sky after sunset at mag. 1.0. Rings tilted Earthward at 8°.

January meteors

The year's most abundant meteor shower, the **Quadrantids**, is visible on January 3 and 4. Its peak of activity is much sharper than that of most showers, lasting only a few hours; the exact time varies from year to year. At best, over 100 Quadrantids can be seen in an hour, although the meteors of this shower are not as bright as other great displays such as the Perseids and Geminids. The Quadrantids radiate from the northern part of Boötes, near the handle of the Big Dipper. This area of the sky was once occupied by the now-defunct constellation Quadrans Muralis, the Mural Quadrant, from which the shower takes its name. Unfortunately this area of sky is not well placed for observation until after midnight, so Quadrantid watchers must be prepared to brave the wee hours of the night to see the shower at its best. Their parent body is thought to be an asteroid called 2003 EH₁, which was probably once part of a comet's nucleus.

Orion

Orion is the most glorious of all constellations. It glitters with bright stars and is replete with objects of interest for observers with all forms of optical equipment, including the humblest binoculars. It is an ideal place to begin a yearly tour of the heavens.

Orion is commonly personified as a hunter, giant, or warrior. On old star charts, he is depicted brandishing his club and shield against the snorting charge of neighboring Taurus, the Bull. In Greek mythology, Orion was the son of Poseidon. He was stung to death by a scorpion in retribution for his boastfulness. At the request of his lover, Artemis, he was placed in the sky so that he sets in the west as his slayer, in the form of the constellation Scorpius, rises in the east. In another story, Orion was smitten by the beauty of the seven nymphs known as the Pleiades, whom he began to pursue. To save the nymphs, Artemis turned them into a cluster of stars. The Pleiades star cluster lies in the neighboring constellation of Taurus, and Orion still seems to chase them in his nightly course across the sky.

Orion is one of the easiest constellations to recognize, lying due south at 10 p.m. this month. Look first at Alpha (α) Orionis, better known as **Betelgeuse**, at the top left of the constellation. Note that it has a distinctly orange color, which is brought out more strongly through binoculars. Betelgeuse marks the right shoulder of Orion. Its name is often mistranslated as "armpit of the central one," but its original Arabic title meant "hand."

Betelgeuse is the type of star known as a red supergiant. It is huge—over 500 times the diameter of the Sun, enough to fill the orbit of Jupiter—and fluctuates in size, leading to unpredictable changes in its brightness between about magnitude 0.0 and 1.3. Keep an eye on the variations of Betelgeuse by comparing it with other stars, particularly Aldebaran and Capella, from time to time. Its distance is not accurately known, but recent determinations place it about 500 light years away, considerably closer than the other bright stars in Orion.

Contrasting with the ruddy hue of Betelgeuse is blue-white **Rigel** at the bottom right of the constellation. Rigel marks Orion's left foot, and, not surprisingly, its name comes from the Arabic, meaning "left foot." Rigel, also known as Beta (β) Orionis, is the brightest star in Orion, magnitude 0.1. It, too, is a supergiant, but it has a much hotter surface, which accounts for its difference in color from Betelgeuse. The temperature of Rigel's surface is 12,000 K (kelvin), while that of Betelgeuse is a relatively cool 3,600 K. Rigel is about 860 light years away, 50 percent farther than Betelgeuse.

Rigel is worth looking at carefully for another reason: It is a double star. It has a companion star of magnitude 6.8 that is difficult to see in the smallest telescopes because of the glare from Rigel itself. The aperture needed to pick out this companion will depend on the steadiness of the atmosphere and how high Rigel is above the horizon. Probably at least 75 mm (3 inches) aperture is required, but the only way to be sure is to look yourself.

One distinctive feature of Orion is the line of three bright stars like shiny studs along his belt: Delta (δ) Orionis (Mintaka), Epsilon (ϵ) Orionis (Alnilam), and Zeta (ζ) Orionis (Alnitak). Each of these stars is of 2nd magnitude, and they lie between about 700 and 2,000 light years away. **Delta Orionis** has a wide 7th magnitude companion star that is easily seen in small telescopes. At the left end of the belt, **Zeta Orionis** is a double star that presents a challenge for amateur telescopes. A 4th magnitude companion lies 2.3 seconds of arc from it. Normally,

stars this far apart should just be divisible in an aperture of 50 mm (2 inches), but the difference in brightness between them means that at least 75 mm (3 inches) aperture is needed to separate them, as well as a night of steady seeing.

A strip of faint nebulosity, known as **IC 434**, extends southward from Zeta Orionis. On one side of this is the celebrated **Horsehead Nebula**, formed by a cloud of dark dust that is silhouetted against the glowing hydrogen gas behind it. Unfortunately, the Horsehead is nearly impossible to see with the eye even through large telescopes, but it shows up well in long-exposure photographs, looking like a celestial chess piece.

A survey of Orion's stellar treasures would be incomplete without a visit to **Sigma (σ) Orionis**, lying just below the left-most star of the belt. To the naked eye, Sigma Orionis is an unremarkable star of 4th magnitude, but small telescopes reveal it to be flanked by three fainter stars, looking like a planet with moons. Also visible in the same field of view is a triple star, **Struve 761**, which consists of a narrow triangle of 8th and 9th magnitude stars. This rich telescopic sight is one of Orion's unexpected delights.

One reason for Orion's prominence is that most of its stars lie in a region of our local spiral arm of the Galaxy where new stars are still being born. The center of starbirth in this region is the **Orion Nebula**, 1,500 light years away, which appears as a misty patch to the naked eye. It marks the sword of Orion, hanging from his belt (see panel below).

Color photographs show the Orion Nebula to be a mixture of yellow and red, whereas to the human eye it appears greenish. The reason lies in the poorer sensitivity of the eye to faint red light than to faint green light. Color images give a better idea of the true color of the nebula than does the human eye.

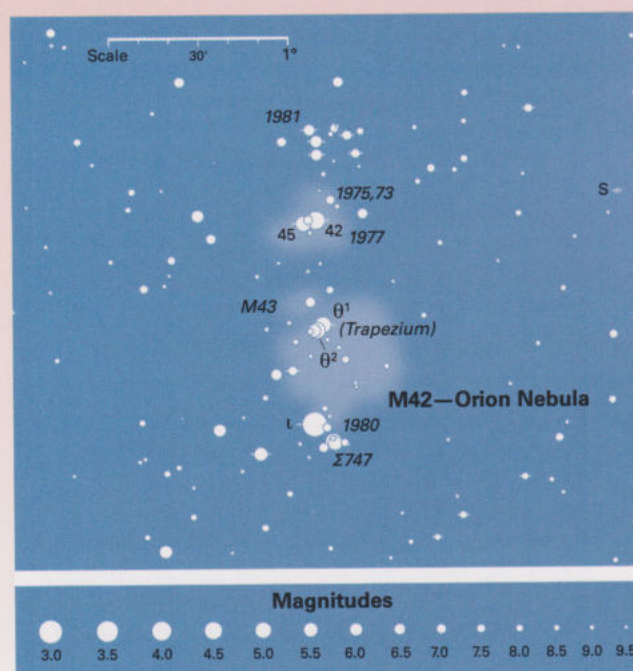
The Orion Nebula is about 20 light years in diameter and contains enough gas to make thousands of stars. If we could turn back the clock 5 billion years to the birth of the Sun, we would find that our region of space looked much like the Orion Nebula.

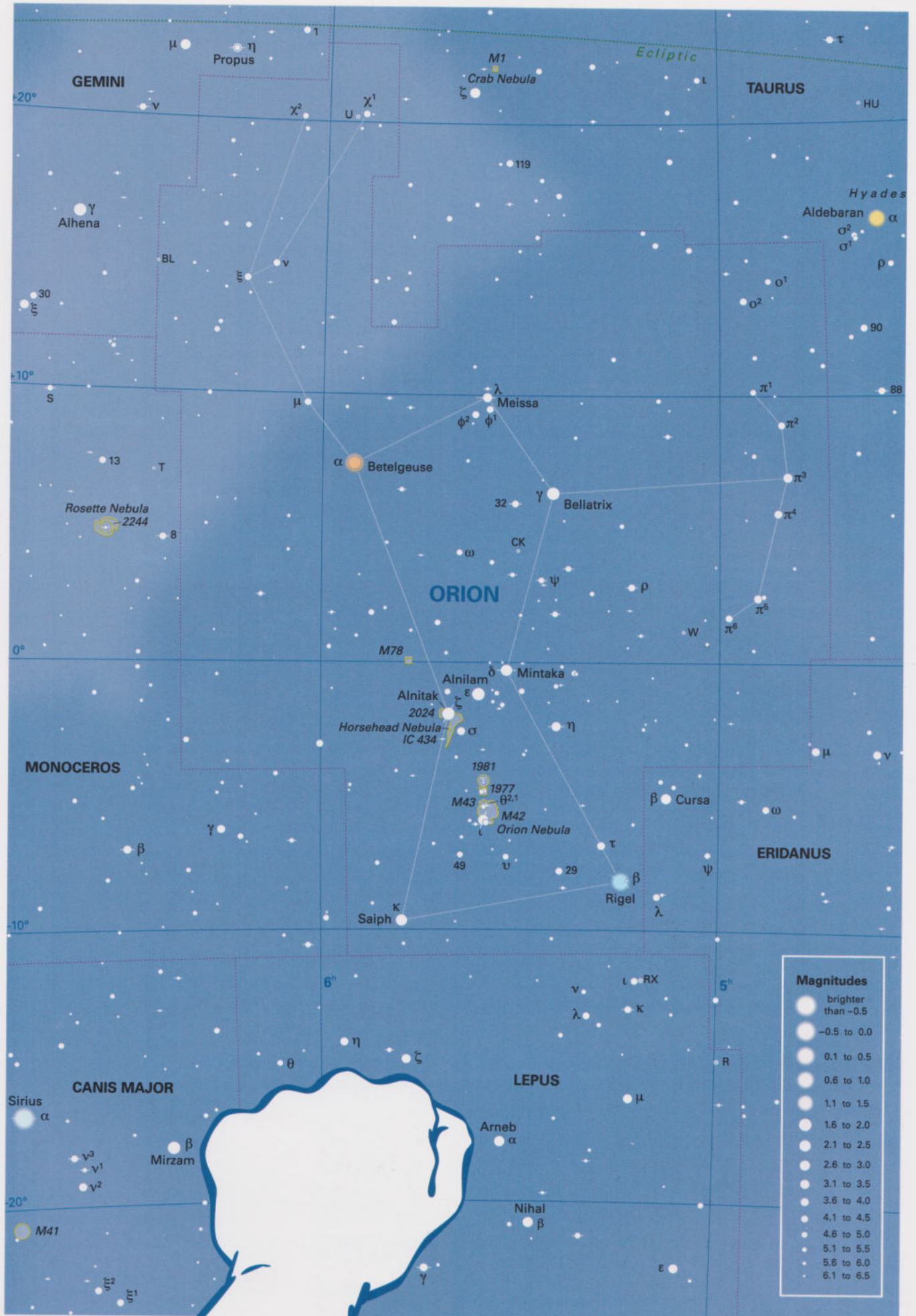
The Orion Nebula

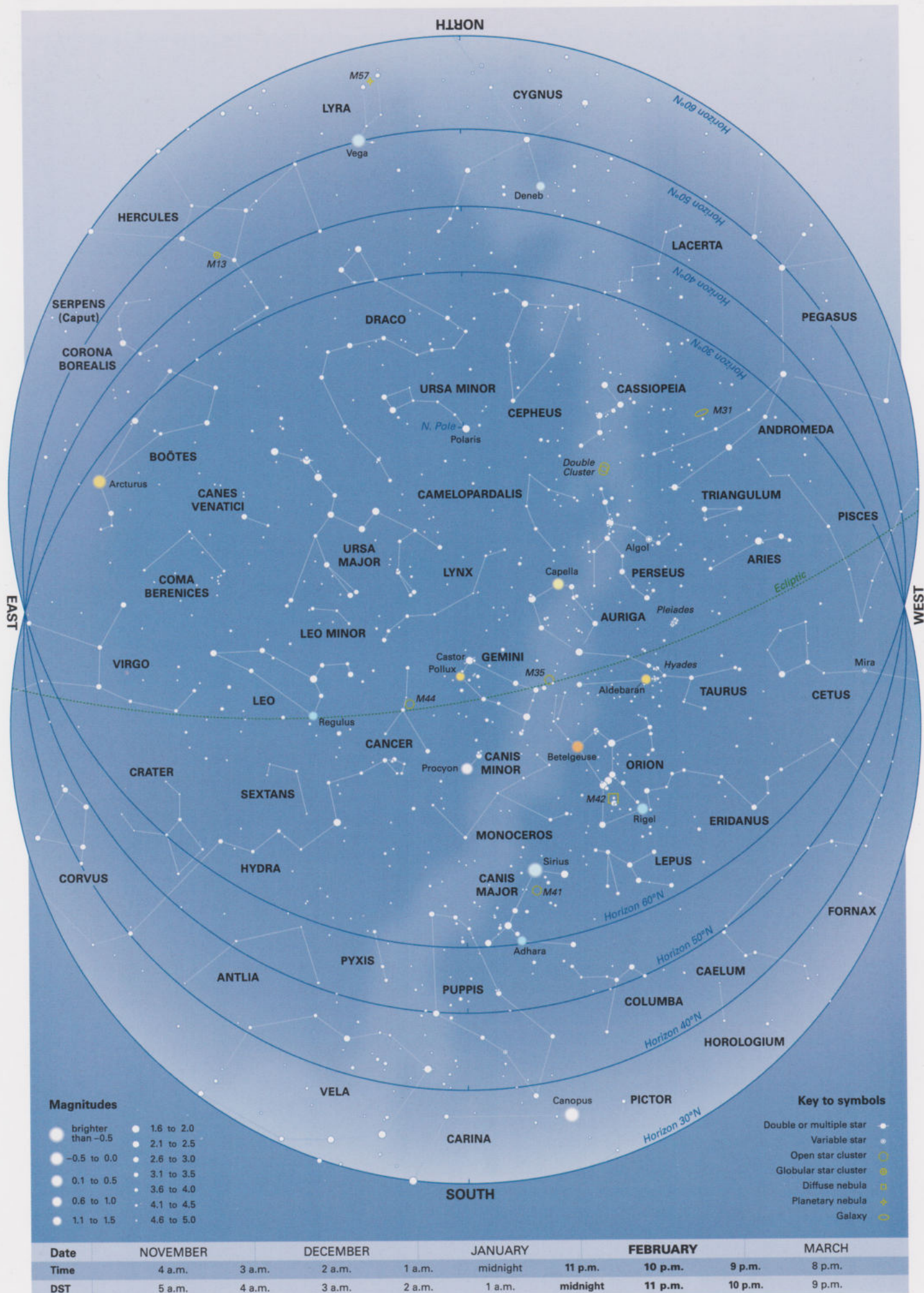
The **Orion Nebula** is a luminous cloud of gas, the finest object of its kind in the heavens, also known as **M42** and **NGC 1976**. Wreaths of ghostly glowing gas spread over a degree of sky, twice the apparent diameter of the full Moon, making a sight not to be missed in any instrument. To its north is a smaller patch of gas, **M43**, alias **NGC 1982**, which is part of the same cloud. Because the Nebula is so large, binoculars are excellent for viewing it. Embedded at the Nebula's center is a 5th magnitude star, **Theta-1 (θ^1) Orionis**. This star was born recently from the surrounding gas, and it illuminates the Nebula. Home in on Theta-1 Orionis with a small telescope, and you will see why it is called the **Trapezium**: It consists of four stars of magnitudes 5.1, 6.7, 6.7, and 8.0, arranged in a rectangle. The Trapezium is almost at the tip of a dark wedge in the Nebula known as the **Fish Mouth**. To the lower left of the Trapezium, binoculars show **Theta-2 (θ^2) Orionis**, a wide double star of magnitudes 5.0 and 6.4.

This whole area is a complex of nebulosity and young, hot stars, which together comprise the sword of Orion. At the tip of the sword, on the southern edge of the Orion Nebula, is **Iota (ι) Orionis**, the brightest star in the sword. Iota Orionis is a hot, blue-white giant of 3rd magnitude with a 7th magnitude companion shown by small telescopes. To the lower right of Iota lies **Struve 747**, an easy pair of 5th and 6th magnitude white stars for small telescopes. Above the Orion Nebula lies a smaller smudge of nebulosity, **NGC 1977**, containing the 5th magnitude star 42 Orionis. (Its apparent neighbor, 45 Orionis,

is an unrelated foreground object.) Farther north, binoculars reveal **NGC 1981**, a scattered handful of stars of 6th magnitude and fainter, marking the top of the sword handle.







February

KEY STARS

The Winter Triangle formed by Sirius, Procyon, and Betelgeuse remains prominent in the evening sky this month. Other stars well-placed for observation are Rigel, in Orion, and Aldebaran, in Taurus, both in the southwest. Castor and Pollux, the twin stars of Gemini, are high in the sky at 10 p.m. At the same time, orange Arcturus is rising on the eastern horizon.

The planets this month

Venus

- 2020 Prominent in the western evening sky at mag. -4.2. Improves in visibility throughout the month as its separation from the Sun increases.
- 2021 Too close to the Sun for observation as it moves toward superior conjunction.
- 2022 Brilliant in the southeastern dawn sky at mag. -4.6, but very low as seen from more northerly latitudes.
- 2023 Low in the western evening sky throughout the month at mag. -4.0. Approaches Jupiter (mag. -2.1) at month's end.
- 2024 Low in the southeastern evening sky at mag. -3.9, becoming lost in twilight as the month progresses.

Mars

- 2020 Low in the southeastern dawn sky, brightening from mag. 1.4 to 1.1 during the month, but too low for observation from more northerly latitudes.
- 2021 In the southwestern evening sky, passing from Aries into Taurus. Ends the month south of the Pleiades at mag. 0.9.
- 2022 Low in the southeastern dawn twilight at mag. 1.2 as seen from mid-northern latitudes and below, but too low for observation from farther north. Lies below brilliant Venus in the second half of the month.
- 2023 An evening object in Taurus, fading from mag. -0.2 to +0.4 during the month.
- 2024 Low in the southeastern dawn sky at mag. 1.3 as seen from more southerly latitudes, but remains too low for observation from mid-northern latitudes and above. Passes just over one Moon diameter from brilliant Venus (mag. -3.9) on February 22.

Jupiter

- 2020 Rises before the Sun in the southeastern dawn sky at mag. -1.9, but remains low from more northerly latitudes.
- 2021 Too close to the Sun for observation.
- 2022 Too close to the Sun for observation as it moves behind the Sun toward conjunction next month.
- 2023 In the western evening sky at mag. -2.1, becoming lower during the month. Forms a striking pair with brilliant Venus (mag. -4.0) at month's end.
- 2024 A prominent evening object in Aries at mag. -2.3.

Saturn

- 2020 Emerges into the southeastern dawn sky by month's end at mag. 0.6, below left of brighter Jupiter (mag. -1.9), but remains low as seen from mid-northerly latitudes and above. Rings tilted Earthward at 22°.

- 2021 Emerges into the southeastern dawn sky at mag. 0.7 ahead of Jupiter at month's end as seen from the most southerly latitudes, but too low for observation farther north. Rings tilted Earthward at 19°.
- 2022 At conjunction (behind the Sun) on February 4 and unobservable throughout the month.
- 2023 At conjunction (behind the Sun) on February 16, and unobservable throughout the month.
- 2024 Rapidly becomes lost in the southwestern evening twilight as it moves toward conjunction (behind the Sun) on February 28.

Canis Major

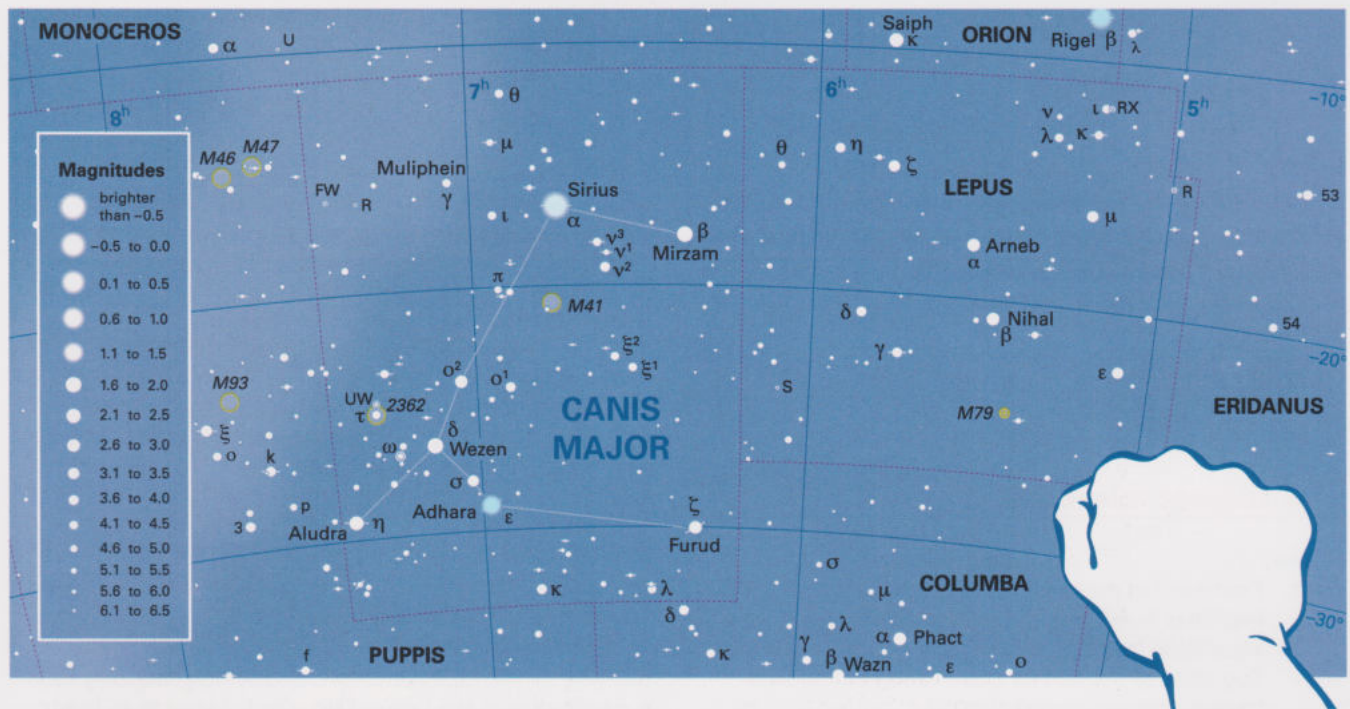
In the south this month sits the constellation Canis Major, the Greater Dog, home of **Sirius**, the brightest star in the entire sky. Canis Major and nearby Canis Minor represent two dogs following at the heels of Orion. Surprisingly, the only object of significance in the Lesser Dog, Canis Minor, is its brightest star, Procyon; hence Canis Minor might be called the lone-star constellation. By contrast, Canis Major is packed with bright stars. On old maps, the dog is depicted standing on his hind legs, with flaming Sirius (known as the Dog Star) marking his snout.

Sirius has a magnitude of -1.46. Its name comes from the Greek, meaning searing or scorching; in ancient times, it was thought to be a source of heat. The sweltering "dog days" of summer were attributed to the Dog Star, for they occurred when Sirius lay close to the Sun. Hesiod, one of the earliest Greek poets, wrote of "heads and limbs drained dry by Sirius." Because of the outstanding brilliance of Sirius, its yearly passage around the sky was used as a calendar marker from at least the time of the ancient Egyptians, over 2,000 years BCE. By chance, it now lies almost exactly due south at midnight on January 1.

Sirius shines twice as brightly in our skies as the second most prominent star, **Canopus**, mag. -0.7, which can be seen below it at this time of year if you are south of latitude 37° north. The exceptional brilliance of Sirius is due to a combination of its light output and its relative closeness to us. Sirius is roughly twice the mass and twice the diameter of the Sun, and it gives out more than twenty times as much light. That by itself is not exceptional. What helps make Sirius so bright in our skies is that it is 8.6 light years away, the fifth-closest star to the Sun. Hence it outshines more powerful stars, such as Betelgeuse in Orion, which are much more distant. Of the stars visible to the naked eye, only Alpha Centauri in the southern hemisphere is closer to us than Sirius.

Sirius is a blue-white star, but it twinkles a multitude of colors as its light is broken up by air currents in the Earth's atmosphere on frosty winter nights. In binoculars or a small telescope, it is dazzling. Sirius has a bizarre 8th magnitude companion, a small and dense star of the type known as a *white dwarf* (see box on next page). This tiny companion of the Dog Star has been nicknamed the Pup. It is so close to Sirius that a large telescope is needed to show it.

Beta (β) Canis Majoris is a blue giant star 500 light years away, magnitude 2.0. It bears the Arabic name Mirzam, meaning "the announcer," because its rising heralds the appearance of Sirius. Beta is not the second-brightest star in the constellation; that honor goes to Epsilon (ε) Canis Majoris, magnitude 1.5, which is another blue giant 400 light years away.



The real superstar of the constellation is easily overlooked: **Eta (η) Canis Majoris**, a brilliant supergiant 100,000 times more luminous than the Sun but appearing to us at a modest 2.4 magnitude because it is about 2,000 light years away. Almost as impressive is **Delta (δ) Canis Majoris**, which the Arabs named Wezen, meaning "weight." The legend behind this odd name has been lost over time. Although the Arabs could not have known, the name is appropriate, since the star is indeed weighty, with an estimated mass at least ten times that of the Sun. The name would have been even better suited to Eta Canis Majoris, which turned out to be heavier still. Delta Canis Majoris is also a supergiant, in this case giving out about 50,000 times as much light as the Sun

and appearing of magnitude 1.8, despite being around 1,600 light years away.

If Sirius were removed to the same distance as Delta or Eta Canis Majoris, it would appear of 11th or 10th magnitude, respectively, way below naked-eye visibility. Conversely, if these two stars were as close to us as Sirius, they would each shine as brilliantly as a half Moon, so the night sky would never be dark when they were above the horizon.

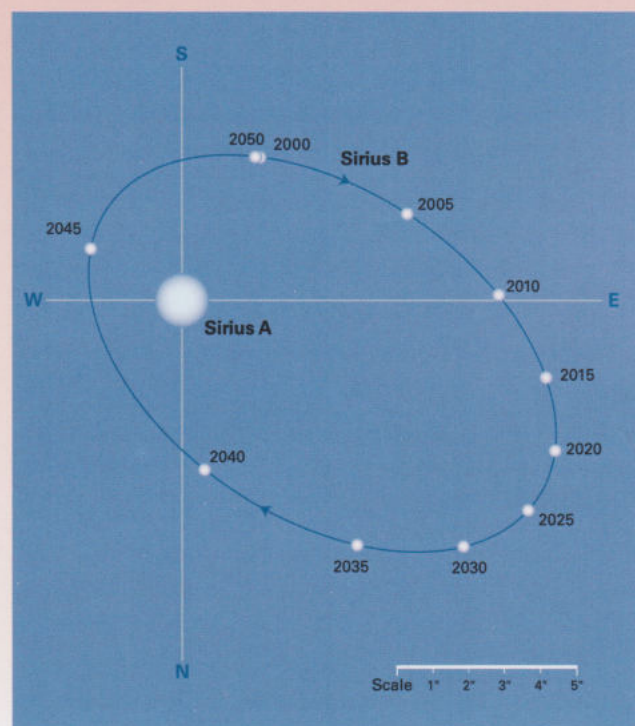
Canis Major contains two attractive star clusters for small instruments. Just south of Sirius is **M41**, an open cluster covering the same area of sky as the full Moon. Under good conditions, it can even be seen as a fuzzy spot by the naked eye. M41 contains about fifty stars, the brightest of them a 7th

White dwarfs

In 1862, American astronomer Alvan G. Clark first saw the faint companion of Sirius while testing a new 470 mm (18½ inch) telescope. But this companion star, **Sirius B**, was a puzzle. Its surface was hotter than that of the Sun, yet the star itself was much dimmer than the Sun. That meant it must be very small—as we now know, it is only about 1 percent of the Sun's diameter, similar in size to the Earth, which is astoundingly small by stellar standards. Such a tiny, hot star is called a white dwarf.

The puzzle did not end there. Sirius B was found to have as much mass as the Sun. That much mass packed into such a small ball meant that Sirius B must be incredibly dense, far denser than any substance known on Earth. A spoonful of material from Sirius B would weigh many tons. Coincidentally, the brightest star in Canis Minor, Procyon, is also accompanied by a white dwarf, fainter and even more difficult to see than the companion of Sirius. White dwarfs are now known to be the dying remnants of stars like the Sun. The companions of Sirius and Procyon have both seen better days.

Sirius B orbits Sirius A once every fifty years (see diagram at right). The two stars are always too close for Sirius B to be seen in small telescopes. Even when the two are at their widest separation, between the years 2020 and 2025, a telescope of at least 200 mm (8 inches) aperture and steady air will be needed to pick out the faint spark of Sirius B from the glare of its brilliant neighbor.



magnitude orange giant. Binoculars pick out the brightest members, and many more are visible in small telescopes. Note how the stars are arranged in chains, a common effect in clusters. Observers in high northern latitudes will find that the proximity of M41 to the horizon dims its splendor.

Much more compact than M41 is **NGC 2362**, another open cluster, centered on the 4th magnitude blue supergiant **Tau (τ) Canis Majoris**. NGC 2362 contains about fifty members, many of them visible in small telescopes. Tau Canis Majoris has a light output of 30,000 Suns. This star and the surrounding cluster are almost 5,000 light years away from us.

Monoceros

Between the stars of the Winter Triangle lies the faint but fascinating constellation of Monoceros, the Unicorn, introduced on star maps in the seventeenth century. Often overlooked in favor of its brilliant neighbors, Monoceros contains some classic objects.

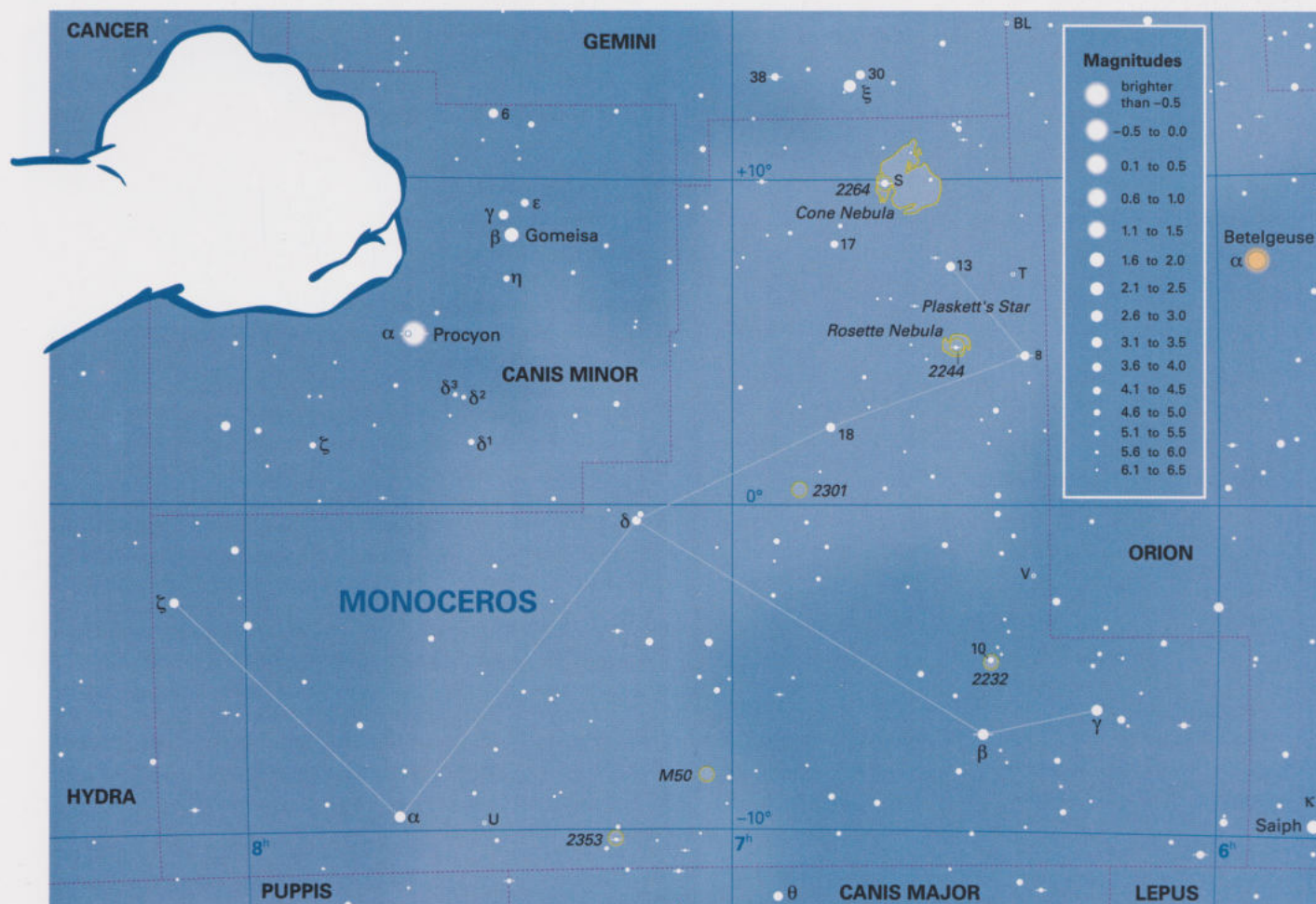
Among them is perhaps the finest triple star for small telescopes, **Beta (β) Monocerotis**. It appears double under low magnification, but a higher power divides the fainter companion. The three stars, all of 5th magnitude, form an arc. **8 Monocerotis**, also known as Epsilon (ϵ) Monocerotis, is a double star easily separated by small telescopes, consisting of blue-white and yellow components of magnitudes 4.4 and 6.6, set among an attractive scattering of fainter stars. The two component stars are unrelated.

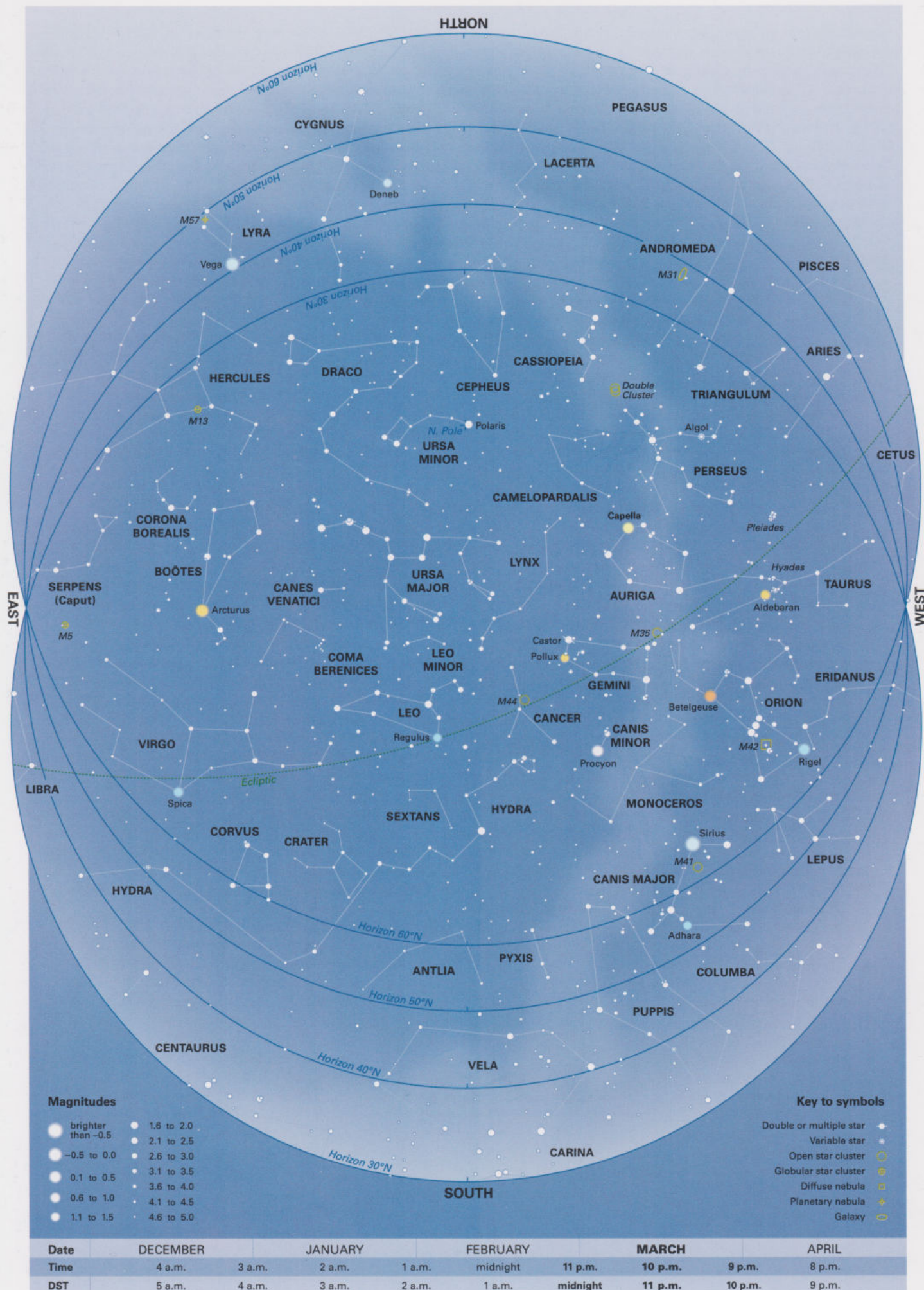
Monoceros contains two celebrated open star clusters, both enveloped by faint nebulosity from which they have recently formed. **NGC 2244** is a widespread group of a dozen or so stars, 6th magnitude and fainter, covering an area similar to the apparent width of the Moon and best seen in binoculars or wide-

field telescopes with low magnification. The hidden treasure of this object is the surrounding gas cloud, known as the **Rosette Nebula**, which looks beautiful in long-exposure photographs. Unfortunately, it is too faint to be seen through small telescopes, although under excellent conditions it might be glimpsed through large binoculars as a faint halo, more than two Moon diameters wide. It lies about 5,000 light years away and is one of the youngest clusters known, with an age of about 3 million years.

About two degrees from NGC 2244 lies 6th magnitude **Plaskett's Star**, named after the Canadian astronomer John Stanley Plaskett, who found in 1922 that it is the heaviest pair of stars known. According to the latest measurements, both stars are blue supergiants more than fifty times as massive as the Sun, which places them firmly in the super-heavyweight class. The two stars are so close together that they cannot be seen individually in any telescope. Only by analyzing light from Plaskett's Star through a spectroscope can astronomers tell that two stars, not one, are present and that they orbit each other every fourteen days. Stars of such immense mass do not live for long, so Plaskett's Star must be very young, probably less than a million years old.

Another of the secret treasures of Monoceros is the open star cluster **NGC 2264**. Small telescopes and binoculars show about a dozen stars arranged in the shape of an arrowhead, with numerous fainter members. Brightest of the cluster is **S Monocerotis**, an intensely hot blue-white star of magnitude 4.7 but slightly variable. NGC 2264 is enveloped in a glowing gas cloud, too faint to see in small telescopes but well known from long-exposure photographs. Into its southern end intrudes a cone-shaped wedge of dark dust, which gives the object its nickname, the **Cone Nebula**. NGC 2264 and the Cone Nebula lie about 2,400 light years away.





March

KEY STARS

Taurus, Orion, and the Winter Triangle are sinking toward the western horizon by 10 p.m. this month. Castor and Pollux are still well displayed, and Capella glints high in the northwest. Regulus, the brightest star of Leo, shines high in the south around 10 p.m. Below it is the straggling figure of Hydra, a region bereft of bright stars. The seven stars that make up the familiar shape of the Big Dipper are well-placed for viewing this month. On the eastern horizon, Spica and Arcturus are rising, heralding the approach of spring.

The planets this month

Venus

- 2020 Brilliant in the western evening sky throughout the month at mag. -4.3 . Reaches greatest elongation (maximum separation) from the Sun of 46° on March 24, when it appears at half phase through telescopes.
- 2021 Unobservable throughout the month as it moves behind the Sun. Superior conjunction is on March 26.
- 2022 In the southeastern dawn twilight at mag. -4.4 . Greatest elongation (maximum separation from the Sun) of 47° is on March 20, when the planet appears at half phase through telescopes, but it remains low from mid and far northern latitudes. Forms a group with first-magnitude Mars and Saturn at month's end.
- 2023 Low in the western evening sky at mag. -4.0 . Forms a brilliant pair with Jupiter at the start of the month.
- 2024 Too close to the Sun for observation all month.

Mars

- 2020 Low in the southeastern dawn twilight, brightening from mag. 1.1 to 0.8, but almost unobservable from more northerly latitudes. Passes brighter Jupiter (mag. -2.1) around March 20 and Saturn (mag. 0.7) at month's end.
- 2021 In the western evening sky in Taurus, passing between the Pleiades and Hyades star clusters in the first half of the month, similar in brightness to first-magnitude Aldebaran but redder.
- 2022 Low in the southeastern dawn sky at mag. 1.2 as seen from mid-northern latitudes and below, but lost in twilight from farther north. Forms a grouping with Venus and Saturn in the last week of March.
- 2023 An evening object, moving from Taurus into Gemini during the month and fading from mag. 0.4 to 1.0.
- 2024 Low in the southeastern dawn sky at mag. 1.2 as seen from more southerly latitudes, but remains too low for observation from mid-northern latitudes and above.

Jupiter

- 2020 In the southeastern dawn sky at mag. -2.1 , but too low for observation from more northerly latitudes. Forms a close pair with fainter Mars, mag. 0.9, around March 20.
- 2021 Emerges into the southeastern dawn sky before sunrise toward the end of the month at mag. -2.0 as seen from more southerly latitudes, but too low for observation at mid-northern latitudes and above.
- 2022 At conjunction (behind the Sun) on March 5 and unobservable throughout the month.

- 2023 Low in the western evening sky after sunset, forming a striking pairing with brilliant Venus at the start of the month. Rapidly becomes engulfed in twilight as it moves closer to the Sun and is unobservable after mid-month.
- 2024 Prominent in the western evening sky at mag. -2.1 , but becomes low from northerly latitudes by month's end.

Saturn

- 2020 In the southeastern dawn sky before sunrise at mag. 0.7, but remaining very low as seen from more northerly latitudes. Forms a trio in the last week of March with Mars (mag. 0.8) and brighter Jupiter (mag. -2.1). Rings tilted Earthward at 21° .
- 2021 Low in the southeastern dawn sky at mag. 0.7, but difficult to see from mid-northern latitudes and above. Rings tilted Earthward at 18° .
- 2022 Emerges into the southeastern dawn sky before sunrise during the month at mag. 0.8, but remains low for northernmost observers. Forms a grouping with brilliant Venus (mag. -4.3) and fainter Mars (mag. 1.1) in the last week of March. Rings tilted Earthward at 14° .
- 2023 Emerges into the southeastern dawn sky before sunrise at mag. 0.9 by the end of the month as seen from more southerly latitudes, but remains too low for observation farther north. Rings tilted Earthward at 10° .
- 2024 Emerges into the southeastern dawn sky at mag. 1.0 by month's end as seen from more southerly latitudes, but remains too low for observation from farther north. Rings tilted Earthward at 5° and difficult to see.

Gemini

Gemini represents the twins of Greek mythology, Castor and Pollux, after whom the constellation's two brightest stars are named. Old star maps show the twins holding hands in the sky. The stars Castor and Pollux mark the heads of the twins.

Castor and **Pollux** are contrasting stars. Although they appear in the same region of the sky and are of similar brightness, they are not related. **Pollux** is closer to us, at a distance of 34 light years, while Castor lies 52 light years away. Pollux, also known as Beta (β) Geminorum, is an orange giant of magnitude 1.1, making it the brighter of the pair.

Castor, Alpha (α) Geminorum, is an astounding family of six stars, all linked by gravity. To the naked eye it appears as a single star of magnitude 1.6. But small telescopes, with high magnification, divide Castor into a dazzling pair of blue-white stars of magnitudes 1.9 and 3.0. They orbit each other every 460 years or so. Castor was the first pair of stars recognized to be in mutual orbit, a discovery announced by William Herschel in 1803. Also present, but less easy to see in small telescopes, is a 9th magnitude red dwarf companion some distance from the brighter pair of stars.

All three stars are themselves close doubles, making Castor a stellar sextuplet. Each pair is so close together that the stars cannot be seen separately through even the largest telescopes. Astronomers discovered that the stars were double by analyzing their light through a spectroscope, when the presence of light from two stars was recognized. Hence the stars are known as *spectroscopic binaries*.

Castor A, the brightest of the components, consists of two stars bigger and brighter than the Sun that orbit each other every nine days. Castor B, the second-brightest component,



consists of another two stars larger than the Sun that orbit each other every three days. The third component, Castor C, consists of two red dwarfs, smaller and fainter than the Sun, which orbit each other in less than a day. They also eclipse each other, causing the brightness of Castor C to vary from magnitude 8.9 to 9.6. All the members of the Castor family were born together from the same cloud of gas and have remained linked by gravity ever since. Try to imagine the view from a planet around one of those stars as you gaze at Castor through a telescope.

Gemini is the home of a large and impressive open cluster, **M35**, near the feet of the twins and close to the border with Taurus. M35 contains over 100 member stars scattered across an area as large as the full Moon. M35 is a fine sight in binoculars, appearing as a mottled patch enveloped in mist. Small telescopes clearly show individual

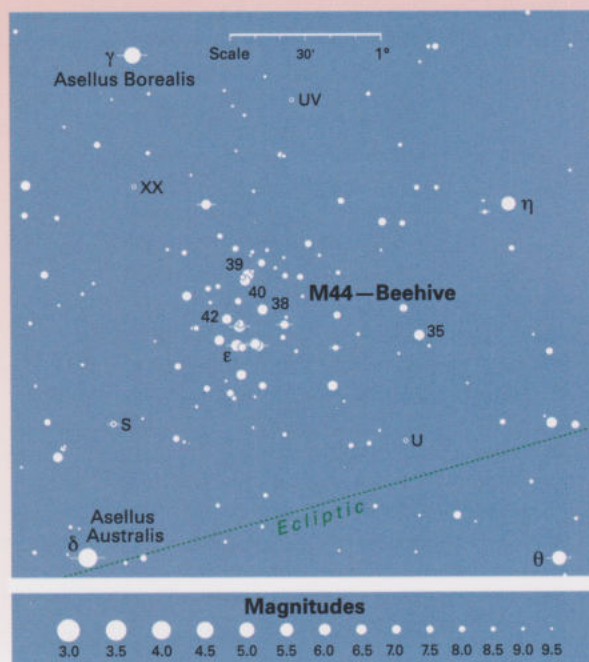
stars of 8th magnitude and fainter. Unlike many clusters, M35 is not condensed at the center. Rather, users of telescopes will note that its stars are arranged in disconnected chains, somewhat reminiscent of the lights on a Christmas tree. M35 lies 3,000 light years away.

More challenging is the planetary nebula **NGC 2392**. Small telescopes show it as a fuzzy, bluish disk like an 8th magnitude star out of focus, of similar size to the globe of the planet Saturn. Here, we are seeing a shell of gas thrown off by a dying star, which appears of 10th magnitude at the center of the nebula. Through large telescopes, NGC 2392 looks like a face surrounded by a fringe; this has given rise to its two nicknames, the **Eskimo Nebula** and the **Clown Face Nebula**. Although you will not see such detail through a small telescope, NGC 2392 is one of the easier planetary nebulae to spot and is well worth searching for.

The Beehive cluster

Between Gemini and Leo lies the constellation of Cancer, the Crab. It is faint, with no star brighter than magnitude 3.5, but at its center lies a classic object for binoculars, the star cluster **M44**. This cluster was known in ancient times as **Praesepe**, the **Manger**, but it is now called the **Beehive**. The cluster is flanked by two stars, known as the **Asses**, visualized as feeding at the Manger. To the north is Gamma (γ) Cancri, magnitude 4.7, called Asellus Borealis, the Northern Ass, while Delta (δ) Cancri, magnitude 3.9, is the Southern Ass, Asellus Australis. M44 is visible to the naked eye on clear nights as a misty patch and was familiar to the ancient Greeks, who kept an eye on it for the purpose of weather forecasting. If the Manger was invisible on an otherwise clear night, this was said to be the sign of a forthcoming storm.

M44 covers $1\frac{1}{2}^\circ$ of sky, three times the apparent size of the full Moon—too large to fit into the field of view of a normal telescope but ideal for binoculars. The Beehive cluster is larger even than the Pleiades in Taurus, although its stars are not so bright. The brightest member of the Beehive is Epsilon (ϵ) Cancri, a white star of magnitude 6.3. In all, M44 contains about twenty stars brighter than 8th magnitude and several dozen more that are brighter than 10th magnitude. Binoculars show the cluster as a breathtaking sight that resembles a swarm of bees around a hive. This stellar beehive lies just under 600 light years away.



Leo

One of the few constellations that genuinely resembles its name is Leo, the Lion. Legend identifies it with the lion slain by Hercules as one of his twelve labors. The Lion's head is represented by a sickle shape of six stars, like a back-to-front question mark. The body is outlined by four stars, the tail being marked by Beta (β) Leonis, a white star of magnitude 2.1 whose name, Denebola, comes from the Arabic, meaning "lion's tail."

At the bottom of the sickle is the brightest star in Leo, Alpha (α) Leonis, better known as **Regulus**, meaning "little king," appropriate for the king of beasts. Regulus appears in our skies as magnitude 1.4. It is a blue-white star 79 light years away, with an estimated diameter three times that of the Sun, and it gives out over 100 times as much light as the Sun. Small telescopes or even binoculars show that Regulus has a widely spaced companion star of 8th magnitude. Although 700 billion km (430 billion miles) from Regulus, more than 150 times the distance of Neptune from the Sun, this companion is genuinely related and moves through space with Regulus.

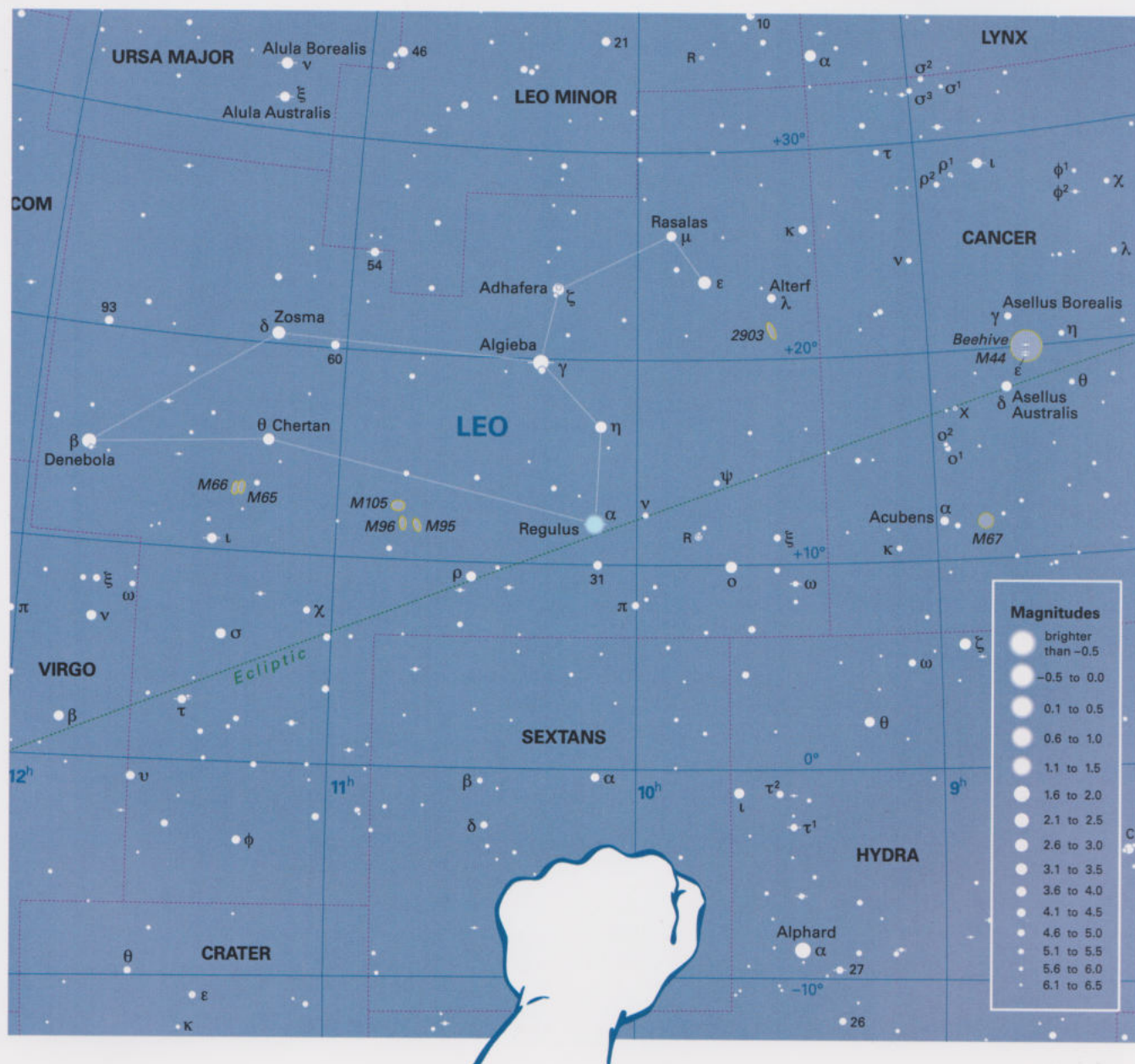
The real showpiece of the constellation is the second-brightest star in the sickle, **Gamma (γ) Leonis**, also known as Algieba. To the naked eye, Gamma Leonis shines at magnitude

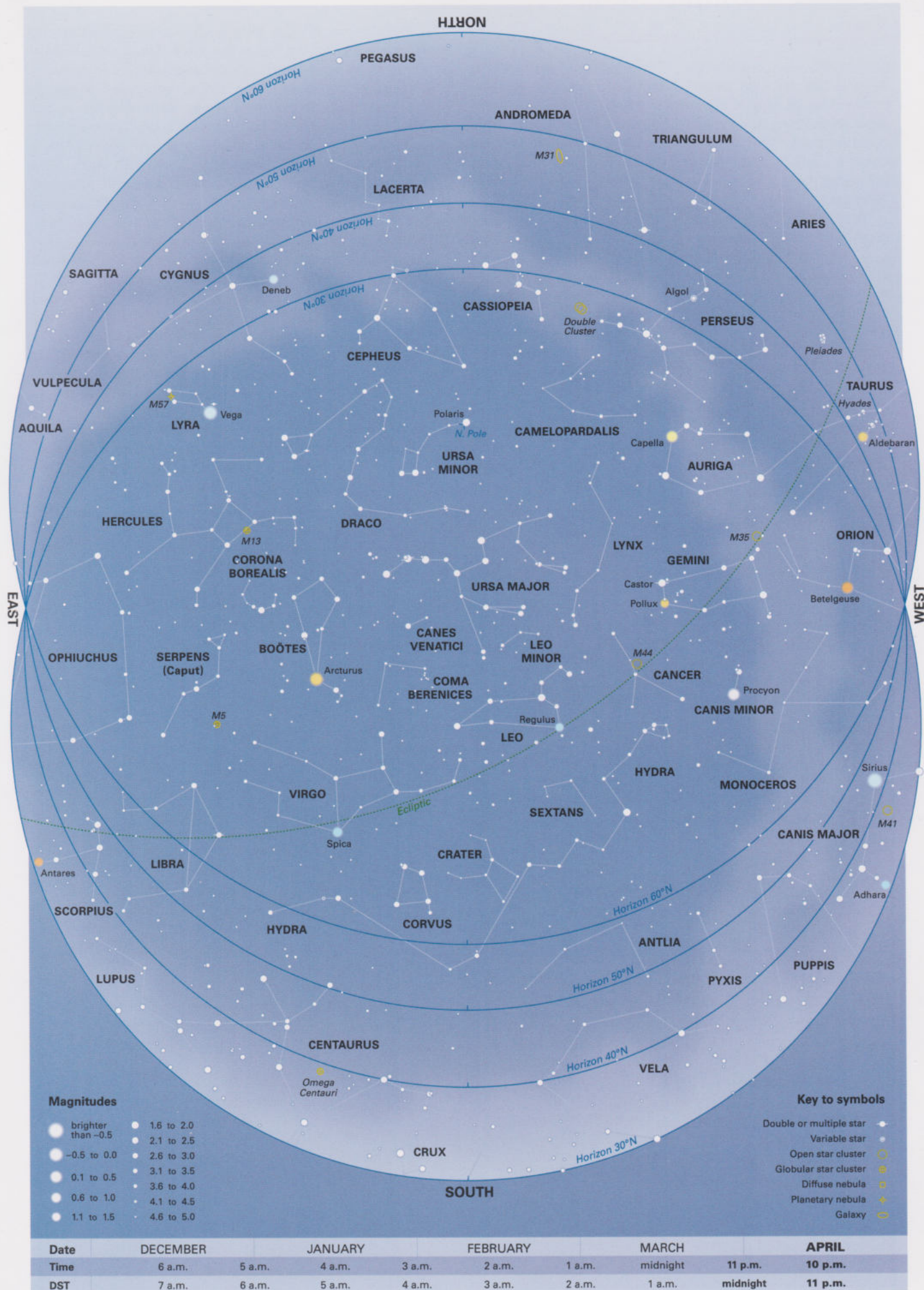
2.0. Binoculars show a 5th magnitude star nearby, 40 Leonis, which is not related but lies in the same line of sight. Turn a small telescope on to Gamma Leonis and switch to an eyepiece that magnifies about 100 times. It splits into a pair of golden yellow stars, one of the most magnificent doubles in the sky. Both components of Gamma Leonis are orange giants, magnitudes 2.4 and 3.6. They orbit their common center of mass every 550 years or so. Gamma Leonis is 130 light years away.

Leo contains a number of galaxies, although none are prominent in small instruments. Between Theta (θ) and Iota (ι) Leonis lie the brightest of the Leo galaxies, **M65** and **M66**, both of 9th magnitude. They are spiral galaxies, but M65 is tilted sideways to us and appears elliptical. In small instruments, M65 and M66 appear as misty patches of light.

If you succeed in finding these, try for the more difficult **M95** and **M96** under the body of Leo. M95 is a barred spiral of 10th magnitude, whereas M96 is an ordinary spiral of 9th magnitude. The structure of each galaxy will not be noticeable in small instruments, for only the brightest central region of each galaxy is visible. All four galaxies lie about 30 million light years away from us.

As with all such faint, hazy objects, their visibility depends on viewing conditions. Under poor skies they will be invisible in even moderate-sized telescopes, but under the best conditions they may be glimpsed in binoculars.





April

KEY STARS

The stars of the Winter Triangle are becoming swallowed in the evening twilight as the days lengthen. The Big Dipper is best placed for observation this month, being overhead at 10 p.m. Follow the curving handle of the Big Dipper to find brilliant Arcturus, and continue the curve to Spica in the southeast. Regulus remains high in the southwest this month while Vega, one of the stars of the Summer Triangle, makes its appearance in the northeast.

The planets this month

Venus

- 2020 Dominates the western evening sky, reaching mag. -4.5 by the end of the month when it appears crescent-shaped through small telescopes.
- 2021 Too close to the Sun for observation all month.
- 2022 In the eastern dawn twilight at mag. -4.2. Forms a brilliant pair with Jupiter at month's end.
- 2023 Prominent in the western evening sky at mag. -4.1.
- 2024 Too close to the Sun for observation all month.

Mars

- 2020 Low in the southeastern dawn twilight, brightening from mag. 0.8 to 0.4.
- 2021 In the western evening sky in Taurus at mag. 1.4, passing into Gemini by month's end.
- 2022 Low in the southeastern dawn sky at mag. 1.0. Passes less than a Moon's diameter from Saturn on April 5.
- 2023 In the western evening sky in Gemini, fading to mag. 1.3 by the end of the month, similar to the star Pollux.
- 2024 Low in the eastern dawn sky at mag. 1.1. Passes one Moon diameter from Saturn, also mag. 1.1, on April 11.

Jupiter

- 2020 In the southeastern morning sky in Sagittarius at mag. -2.2. Fainter Saturn, mag. 0.6, is to the lower left.
- 2021 Low in the southeastern dawn sky at mag. -2.1 as seen from mid-northern latitudes and below.
- 2022 Emerges into the eastern dawn twilight at mag. -2.1 as seen from more southerly latitudes. Ends the month close to dazzling Venus.
- 2023 At conjunction (behind the Sun) on April 11 and unobservable throughout the month.
- 2024 Low in the western evening sky after sunset at mag. -2.0, becoming lost in twilight during the month.

Saturn

- 2020 In the southeastern morning sky at mag. 0.6, but remaining low for more northerly observers. Passes just above Mars at the start of the month, with brighter Jupiter above right. Rings tilted Earthward at 21°.
- 2021 In the southeastern morning sky at mag. 0.7, remaining low for northerly observers. Rings tilted Earthward at 17°.
- 2022 In the southeastern dawn sky at mag. 0.9, but remains low as seen from more northerly latitudes. Passes fainter Mars (mag. 1.0) in the first week of April, to the right of brilliant Venus. Rings tilted Earthward at 13°.
- 2023 In the southeastern dawn sky at mag. 1.0, although remaining too low for observation from northerly

latitudes. Rings tilted Earthward at 9°.

- 2024 In the southeastern dawn sky at mag. 1.1 as seen from more southerly latitudes. Passes one Moon diameter from Mars, also mag. 1.1, on April 11. Rings tilted Earthward at only 4° and difficult to see.

Eclipses

Sun

- 2022 April 30. Partial solar eclipse, maximum 64 percent, visible from the southeastern Pacific Ocean and the southern half of South America.
- 2023 April 20. Annular/total solar eclipse, visible from East Timor and West Papua; maximum duration of totality 1m, 16s. A partial eclipse is visible in the southern Indian Ocean, Australia, southeast Asia, and the western Pacific Ocean.
- 2024 April 8. Total solar eclipse, visible from the eastern Pacific Ocean, Mexico, the eastern United States, and eastern Canada; maximum duration 4m, 28s. A partial eclipse is visible across North and Central America and the Caribbean.

April meteors

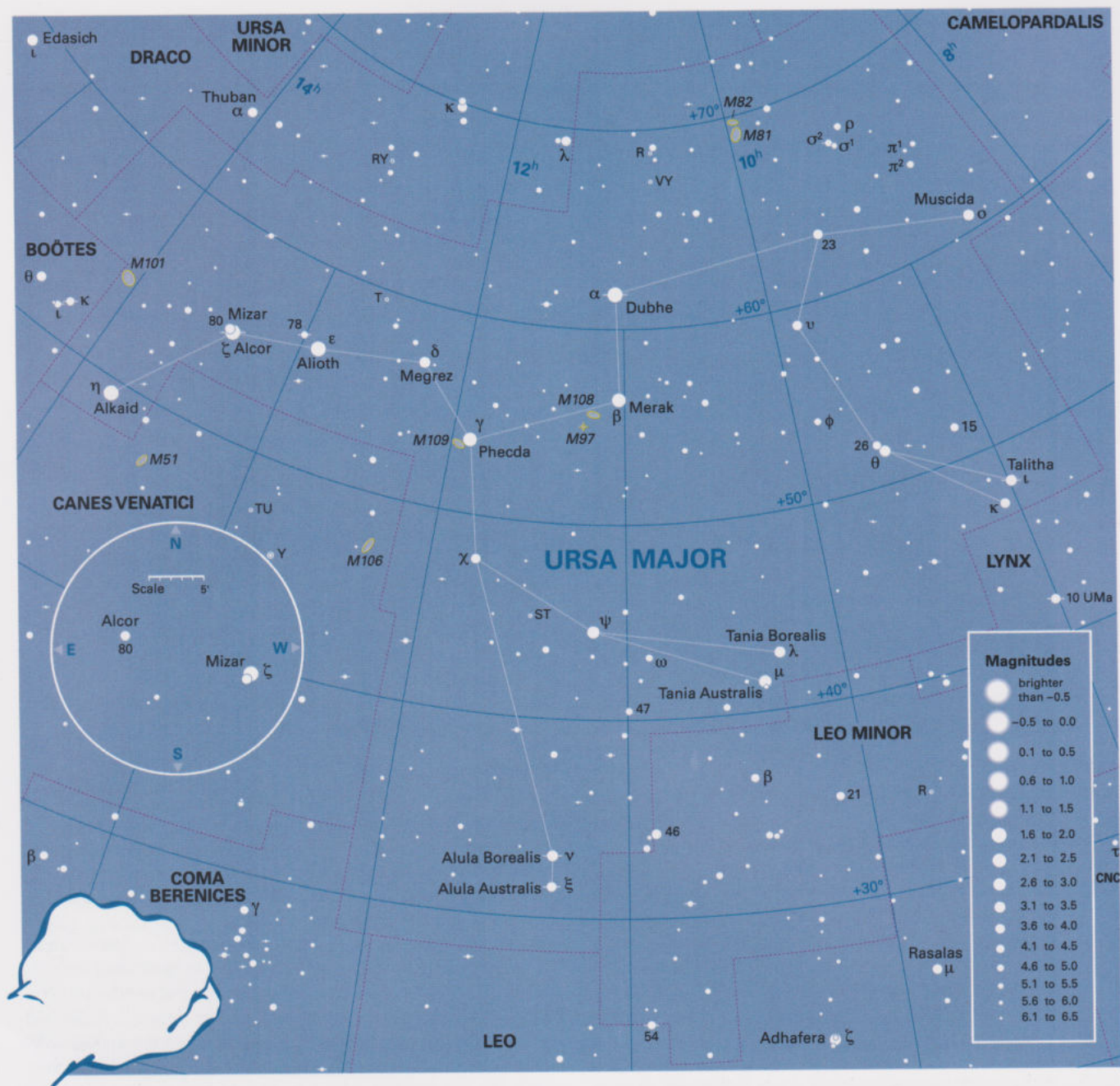
One of the year's lesser meteor showers, the **Lyrids**, makes its appearance this month. At best about a dozen meteors are visible each hour, radiating from a point on the border between Lyra and Hercules, near the bright star Vega. Although not numerous, the Lyrids are impressive. A typical Lyrid is bright and fast and leaves a luminous train. Maximum occurs on April 21 or 22—the exact date varies from year to year—with activity declining rapidly a day or so either side of the maximum. The Lyrids are one of the oldest known meteor showers. Recorded sightings go back more than 2,000 years, when the shower was much more abundant. Their parent body is Comet Thatcher, which has the longest orbital period of any comet associated with a meteor shower, 415 years.

Ursa Major

The two bears, Ursa Major and Ursa Minor, stand high in the sky on spring evenings. Ursa Major's seven brightest stars comprise one of the most easily recognized patterns in the sky, the **Big Dipper**. Myths and legends concerning this star group stretch back to the earliest recorded times. We know the constellation as the Great Bear, although it is a strange-looking bear with a long tail. In Greek mythology, Ursa Major represents the nymph Callisto, who was seduced by Zeus and was subsequently set among the stars in the form of a bear. One version of the tale identifies the Little Bear as her son, Arcas. Another story from ancient Greece says that they are both female bears, representing the nymphs Adrasteia and Io, who raised Zeus when he was an infant.

Ursa Major is the third-largest constellation in the sky. The seven stars that make up the familiar saucepan shape of the Big Dipper are only part of the complete constellation, forming the rump and tail of the bear. All the stars of the saucepan are of 2nd magnitude except Delta (δ) Ursae Majoris, which is 3rd magnitude.

Unlike most constellations, in which the brightest stars have no connection with each other, five of the seven stars in the



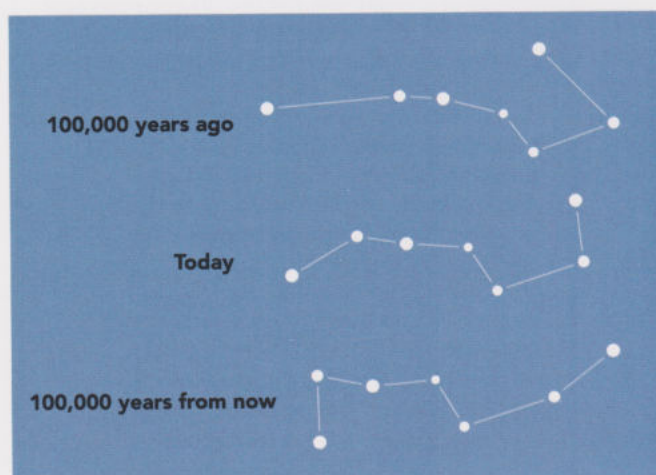
saucepan are related, moving at the same speed and in the same direction through space. These five stars were evidently born together and now form a very scattered cluster. The two non-members of the cluster are Alkaid (Eta Ursae Majoris), at the end of the handle, and Dubhe (Alpha Ursae Majoris), in the bowl. Over long periods of time, the motions of Alkaid and Dubhe relative to the other five stars considerably alter the familiar saucepan shape (see the diagram at right).

The most celebrated star of Ursa Major is situated at the bend of the saucepan's handle, second from the end. It is **Zeta (ζ) Ursae Majoris**, known as **Mizar**, magnitude 2.2. Keen eyesight shows a 4th magnitude star, **Alcor**, nearby. Mizar and Alcor are sometimes called the horse and rider. They lie just over 80 light years away, but they are too far apart to form a genuine binary. However, they are moving through space together, along with the other members of the Ursa Major cluster.

If you look at Mizar through a small telescope, you will see that it has a much closer companion of 4th magnitude

that is definitely associated with it. Precise observations over more than two centuries have confirmed that this star is very slowly moving around Mizar on an orbit that takes about 10,000 years to complete.

This close companion to Mizar was discovered in 1650 by the Italian astronomer Giovanni Riccioli. It made Mizar the first double star to be discovered with a telescope, and



Out of shape: All stars are on the move, gradually altering the shapes of constellations. Here are the stars of the Big Dipper as they appeared 100,000 years ago, as they are today, and as they will look 100,000 years from now.

The Whirlpool galaxy

Just over the border from Ursa Major, in the constellation of Canes Venatici, the Hunting Dogs, lies **M51**, a celebrated spiral galaxy known as the **Whirlpool**. It was the first galaxy in which spiral structure was noted, as seen by the Irish astronomer Lord Rosse in 1845. A remarkable feature of the Whirlpool is the satellite galaxy at the end of one of its spiral arms, as pictured in long-exposure photographs. M51, of 8th magnitude, can be glimpsed under good conditions in binoculars as a misty patch. Small telescopes should show the starlike central nuclei of the Whirlpool and its satellite, but large telescopes are needed to trace its spiral arms. The Whirlpool Galaxy lies about 26 million light years away from us.

it was one of several “firsts” for Mizar. Mizar was also the first double star to be photographed, by George P. Bond at Harvard in 1867; it was the first star discovered to be a spectroscopic binary, by Edward C. Pickering at Harvard in 1889; and it is often the first double star that amateur astronomers turn to with their telescopes. A spectroscopic binary is a pair of stars that are too close together to be seen separately in a telescope and whose double nature can be inferred only from its spectrum. Mizar’s 4th magnitude companion is also a spectroscopic binary, making Mizar a four-star family. Alcor is another spectroscopic binary, completing a remarkable stellar grouping.

Another famous double, although far more challenging, is **Xi (ξ) Ursae Majoris**. It was the first double star to have its orbit calculated, in 1828, a demonstration that the same laws of gravity that govern the orbits of planets around the Sun apply to the stars. The two components, of magnitudes 4.3 and 4.8, orbit each other every sixty years, and the movement is so rapid that it can be followed from year to year in amateur telescopes. When the stars were closest together, around 1993, a telescope of 150 mm (6 inches) aperture was needed to separate them, but since 2017 they have been within range of 60 mm (2.4 inch) telescopes. As seen from Earth, the stars will reach their widest separation around the year 2035, after which they will close up again, reaching their closest once more in 2052.

Ursa Major is the home of several galaxies that lie far outside the Milky Way. In the northern part of the constellation lie M81 and M82, a prominent duo. **M81** is one of the most beautiful spiral galaxies and, at 7th magnitude, one of the easiest to see in small instruments. It appears as a milky-white blur almost half the apparent diameter of the full Moon, much brighter toward its center and somewhat elliptical in shape because it is tilted at an angle to us. Under clear, dark skies, you can pick it out in binoculars. M81 is similar to the great spiral galaxy in Andromeda, M31, although not as large.

Half a degree to the north of M81, and visible in the same low-power field of view, is a more peculiar galaxy, **M82**, which appears cigar-shaped. M82 is smaller than M81 and only one-quarter as bright. For many years, M82 was thought to be an exploding galaxy, but it is actually a spiral galaxy that was disturbed after brushing past M81 about 600 million years ago. It appears elongated because we see it edge-on. M82 and M81 both lie about 12 million light years away from us.

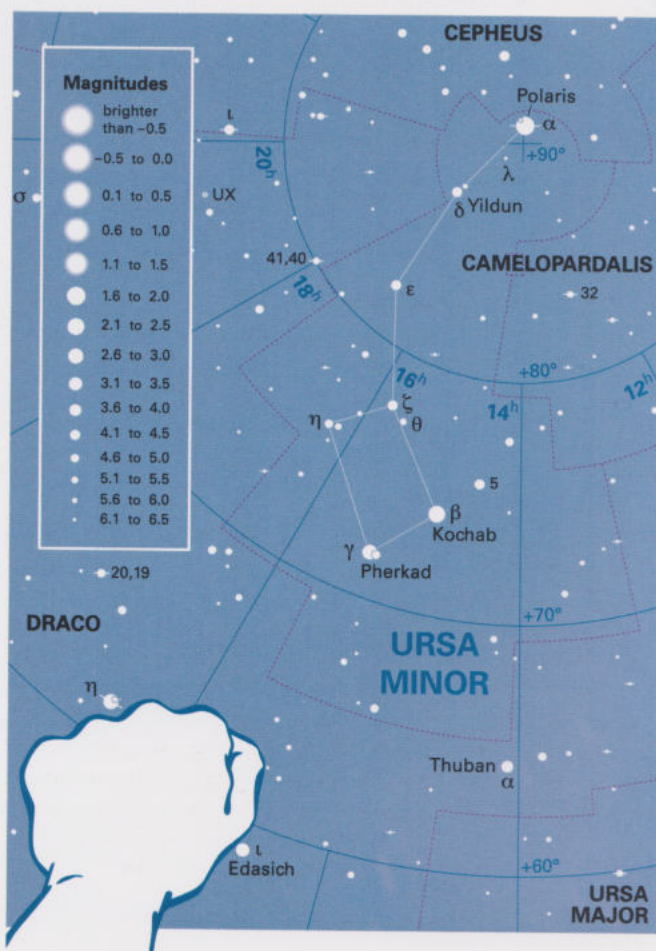
Another major galaxy in Ursa Major is **M101**, a face-on spiral around 22 million light years away. It lies north of the end of the Big Dipper’s handle, forming a triangle with Alcor and Alkaid. Through binoculars and small telescopes, M101 appears as a large, pale disk. Clear, dark skies are needed to see it.

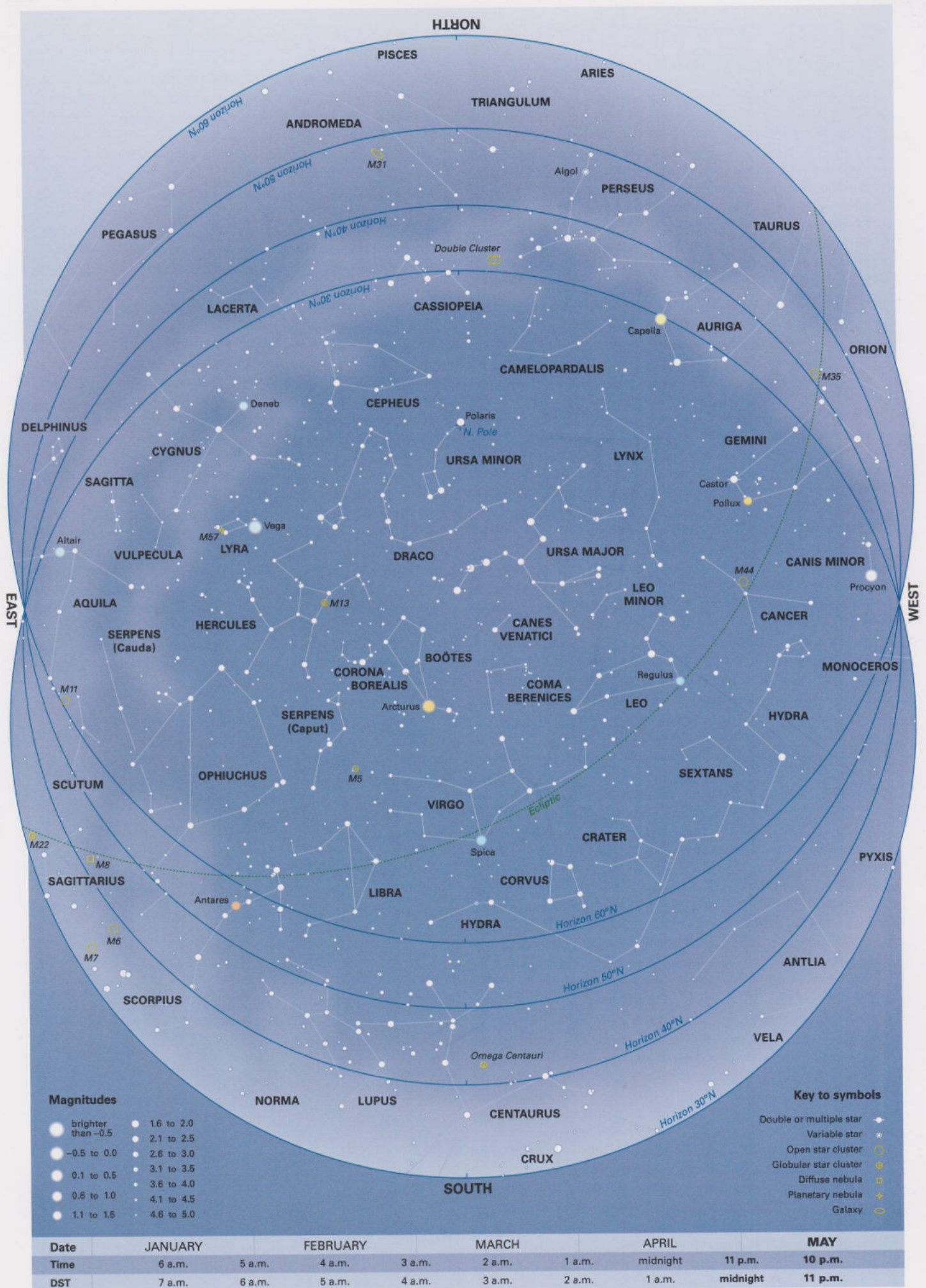
Ursa Minor

The Little Bear, Ursa Minor, looks like a smaller but fainter version of Ursa Major. Its stars form a saucerpan shape reminiscent of the Big Dipper, but with the curve of its handle reversed. Unlike Ursa Major, the stars of the Little Dipper are not related. Two stars in the Little Dipper’s bowl, **Beta (β) Ursae Minoris, Kochab**, of 2nd magnitude, and **Gamma (γ) Ursae Minoris, Pherkad**, of 3rd magnitude, are known as the **Guardians of the Pole**. Keen eyesight, or binoculars, shows that Pherkad has a wide 5th magnitude companion, which is actually an unrelated foreground star. Note that the faintest star in the bowl, **Eta (η) Ursae Minoris**, consists of two widely spaced 5th magnitude stars, also unrelated.

The most famous star in Ursa Minor is Alpha (α) Ursae Minoris, better known as **Polaris**, the Pole Star. It lies less than a degree (two Moon diameters) from the celestial north pole, so it is directly overhead to an observer at the Earth’s north pole. Although it shines modestly at magnitude 2.0 as seen from Earth, if we traveled 430 light years to its vicinity, we would find that it is a rather imposing star—a yellow supergiant perhaps 100 times the Sun’s diameter and giving out as much light as 2,500 Suns. Through a telescope, Polaris appears like a pearl strung on a necklace of fainter surrounding stars.

Telescopes reveal that Polaris is a double star with an 8th magnitude companion, although this partner is difficult to detect in the smallest apertures because of the brightness difference. The companion slowly orbits Polaris over many thousands of years. Polaris is the remarkable case of a Cepheid variable that has almost stopped pulsating. Its variations, originally a tenth of a magnitude or so, progressively decreased during the twentieth century, stabilizing in the 1990s at a few hundredths of a magnitude. More recently, the pulsations have started to build up again, although it is not known how large they may become.





May

KEY STARS

Orange Arcturus blazes high overhead, while Spica glints in the south. Castor and Pollux are sinking toward the western horizon, followed by Regulus and the stars of Leo. Ursa Major still stands high in the north. In the east, the stars of the Summer Triangle, led by blue-white Vega, are rising. Ruddy Antares is climbing into view in the southeast, although it is still low on the horizon for observers above 50° north. For more southerly observers, this is the best month to sweep the rich starfields of Centaurus and Lupus, now well above the southern horizon.

The planets this month

Venus

- 2020 Becomes lost in the evening twilight during the month, low in the west after sunset.
- 2021 Swamped by evening twilight throughout the month.
- 2022 Starts the month less than one Moon diameter from Jupiter in the eastern dawn sky, but too low to see well from more northerly latitudes.
- 2023 Prominent in the western evening sky at mag. -4.3.
- 2024 Unobservable as it moves behind the Sun toward superior conjunction early next month.

Mars

- 2020 Low in the southeastern dawn twilight, brightening from mag. 0.4 to 0.0.
- 2021 Low in the western evening sky at mag. 1.6. Becomes engulfed in twilight by mid-month as seen from more northerly latitudes.
- 2022 In the eastern dawn sky at mag. 0.8, but remaining very low as seen from more northerly latitudes. Forms a close pairing with brilliant Jupiter in the last week of May.
- 2023 In the western evening sky after sunset at mag. 1.4, becoming swamped by twilight from more northerly latitudes after mid-month.
- 2024 Emerges from the eastern dawn twilight during the month at mag. 1.1, very low from northerly latitudes.

Jupiter

- 2020 A morning object in Sagittarius, near the border with Capricornus, brightening from mag. -2.3 to -2.6 during the month. Fainter Saturn, mag. 0.5, lies to its left.
- 2021 Low in the southeastern dawn sky at mag. -2.3 as seen from mid-northern latitudes and below.
- 2022 In the eastern dawn sky at mag. -2.2, but too low for observation from more northerly latitudes. Forms a prominent pair at the start of the month with dazzling Venus, and at the end of the month passes fainter Mars.
- 2023 Emerges into the eastern dawn sky at mag. -2.1 by month's end as seen from southerly latitudes, but too low for observation from mid-northern latitudes and above.
- 2024 At conjunction (behind the Sun) on May 18, and unobservable all month.

Saturn

- 2020 A morning object in Capricornus, near the border with Sagittarius, at mag. 0.5. Forms a pair with brilliant Jupiter to its right throughout the month. Rings tilted Earthward at 21°.

- 2021 A morning object in Capricornus at mag. 0.7. Rings tilted Earthward at 17°.
- 2022 In the southeastern morning sky in Capricornus at mag. 0.8. Rings tilted Earthward at 12°.
- 2023 A morning object in Aquarius at mag. 1.0, remaining very low as seen from the most northerly latitudes. Rings tilted Earthward at 8°.
- 2024 In the southeastern morning sky at mag. 1.2. Rings tilted Earthward at only 3° and difficult to see.

Eclipses

Moon

- 2021 May 26. Total lunar eclipse, visible from North America, Central America, western and southern South America, the Pacific Ocean, Australasia, and east Asia. Totality starts at 11h 10m GMT, ends 11h 27m GMT.
- 2022 May 16. Total lunar eclipse, visible from Africa, western Europe, the Atlantic Ocean, South America, Central America, North America except the far west, and the eastern Pacific Ocean. Totality starts at 03h 29m GMT, ends 04h 54m GMT.

May meteors

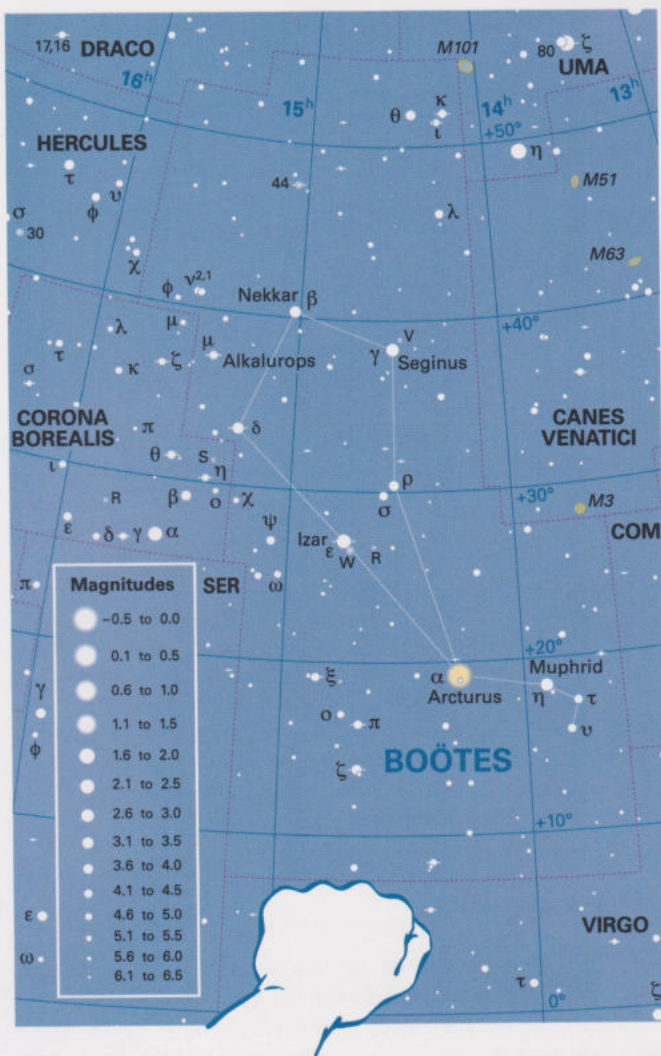
Dust from Halley's Comet can be seen burning up in the atmosphere this month, producing the **Eta (η) Aquariid** meteor shower. At the shower's best, around May 5–6 each year, about thirty-five swift-moving meteors per hour radiate from near the star Eta (η) Aquarii, in the northern part of Aquarius. The shower's peak is broad, and activity remains high for several days either side of the maximum. The shower is difficult to see from the northern hemisphere for two reasons. Since the radiant lies almost on the celestial equator, observers need to be south of latitude 40° north to have much hope of seeing any Eta Aquariids at all. Additionally, the radiant does not rise until nearly 2 a.m., and from northern latitudes it does not get very high in the sky before dawn, which considerably restricts observations. In all, this is a difficult shower to observe.

Boötes

High in the spring sky stands the large constellation of Boötes, the Herdsman. It is easily found, lying next to the tail of Ursa Major. According to legend, Boötes and Ursa Major are inextricably linked. In some tales Boötes is a man plowing or driving a wagon (Ursa Major was often a wagon as well as a plow), while in other legends he is a herdsman or hunter chasing the Great Bear around the pole.

The constellation's brightest star is **Arcturus**, which is Greek for "bear keeper." It was an important star to the ancient Greeks, who used its rising and setting as a guide to the changing seasons. Nowadays, the reappearance of Arcturus in the early evening signifies that spring is approaching.

At magnitude -0.05, Arcturus is the fourth-brightest star in the entire sky, marginally brighter than Vega in Lyra (page 49). Look carefully and you will see that it has an orange tint, which is more prominent when viewed through binoculars. Arcturus is the type of star known as a red giant. It appears red (or more strictly orange) because it has a relatively cool surface temperature, two-thirds that of the Sun. And it is indeed a giant, with a diameter twenty-seven times that of the Sun. Arcturus gives out over 100 times as much light as the Sun, and it lies 37 light years away.



Although Arcturus is so much bigger and brighter than the Sun, the two stars are quite similar in mass. So why do they appear so different? Arcturus is nearing the end of its life, while the Sun is still in middle age. As stars age, they swell up in size to become red giants. One day our Sun will turn into a red giant, although fortunately not for several billion years. So when you look at Arcturus, you are seeing a preview of the Sun as it will be in 5 billion years. When the Sun becomes a red giant, the Earth and all life on it will be roasted to a cinder. Perhaps Arcturus once had a life-bearing planet.

Boötes is well stocked with attractive double stars, but the most celebrated of them is very difficult to divide in small amateur telescopes because the components are so close together. The star concerned is **Epsilon (ε) Boötis**, known as Izar, "the girdle," or unofficially Pulcherrima, meaning "most beautiful," because of the contrasting colors of its stars. To the naked eye, it appears of magnitude 2.4, but it consists of an orange giant of magnitude 2.5 and a greenish-blue companion of magnitude 4.8. They are 2.9 seconds of arc apart, which would be within the power of a 50 mm (2 inch) refractor to split if they were of similar brightness. The brightness difference means that the fainter star is difficult to separate from the primary's glare with even a 75 mm (3 inch) telescope. High magnification and very steady air are needed to divide the two, but the pair provide a stunning sight to those who succeed.

As an easier task, turn to **Kappa (κ) Boötis** in the north of the constellation, consisting of 5th and 7th magnitude white stars easily divisible in small telescopes. A similar but closer pair is **Pi (π) Boötis**, in the south of the constellation. For a warmer-toned pair, find **Xi (ξ) Boötis**, a 5th magnitude golden-yellow star with a 7th magnitude orange companion that orbits it every 150 years. Their distinct hues make them a showpiece duo.

More complex is the magnitude 4.3 white star **Mu (μ) Boötis**, whose name Alkalurops comes from the Arabic referring to the Herdsman's crook or staff. Binoculars show that it has a 7th magnitude companion. This companion star is a close double whose components orbit each other every 260 years or so. These components can be split in telescopes of 75 mm (3 inches) aperture with high magnification.

Virgo

In the south around 10 p.m. this month lies the second-largest of all the constellations: Virgo, the Virgin. She is usually depicted as a maiden holding an ear of wheat, represented by the bright star Spica. She is identified with Demeter, the harvest goddess. But Virgo has a second identity: the goddess of justice. In this guise she is depicted holding the scales of justice, represented by the neighboring constellation Libra.

Despite its large size, Virgo is not a prominent constellation, with the notable exception of blue-white **Spica**, magnitude 1.0. Spica is over twice as hot as Sirius and 100 times more luminous. But in our skies, Spica appears fainter than Sirius because of its considerably greater distance, 250 light years.

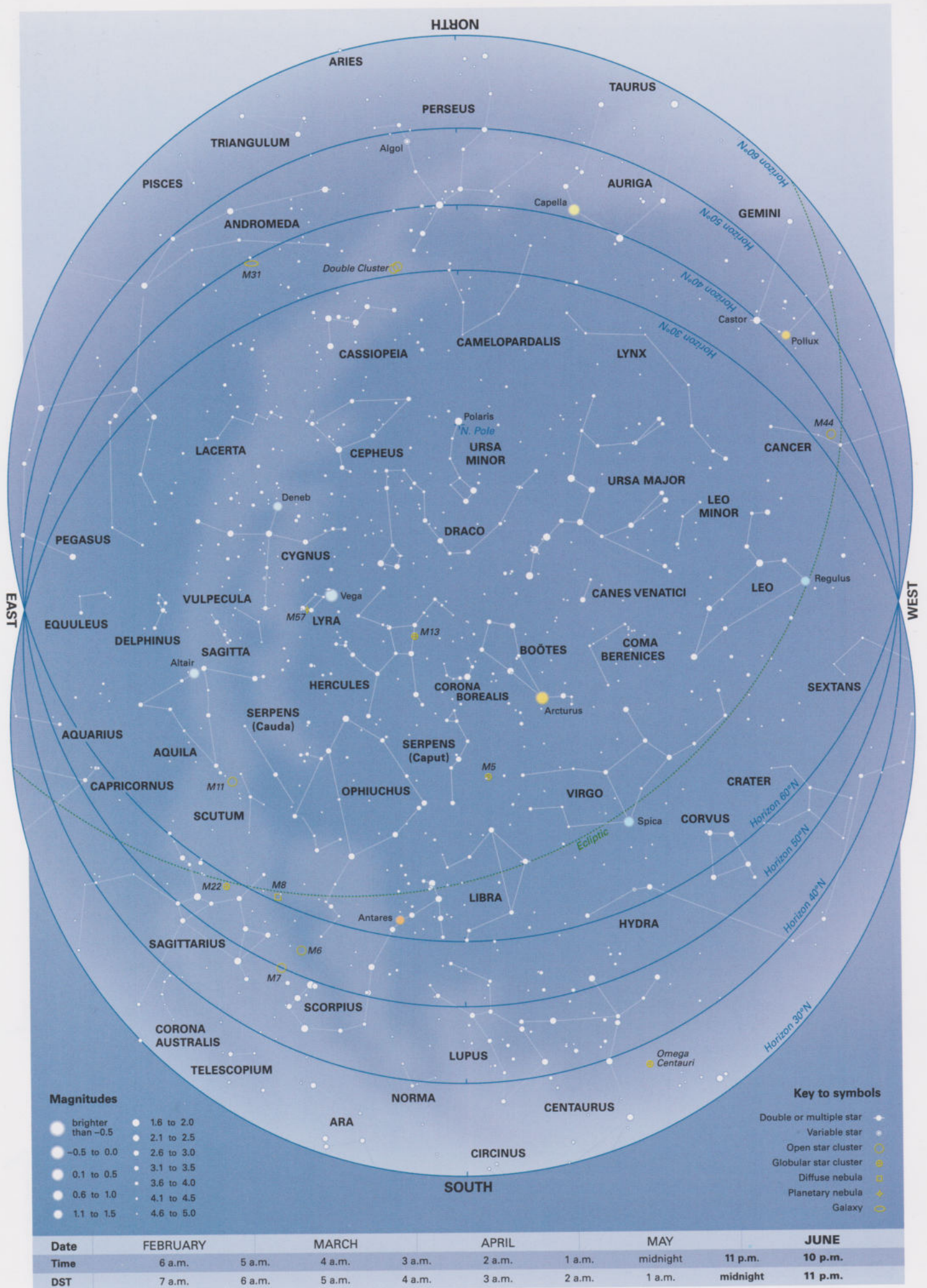
Virgo contains one of the most celebrated double stars, **Gamma (γ) Virginis**, also called Porrima after a Roman goddess of prophecy. To the naked eye Gamma Virginis appears as a star of magnitude 2.7, but it consists of a pair of identical white stars, each of magnitude 3.5, which orbit each other every 169 years. Their orbital motion is noticeable in small telescopes. The two stars were closest together in 2005, when they were indivisible in apertures below about 250 mm (10 inches). They have since moved apart to become an easy object for small telescopes and will remain so for the rest of the twenty-first century.

Virgo's secret treasure is a cluster of distant galaxies, which spills across its northern border into Coma Berenices. The **Virgo Cluster** contains about 3,000 galaxies, centered on the giant elliptical galaxy **M87**, which is visible as a 9th magnitude smudge in small telescopes or even binoculars. M87 is known to radio astronomers as the powerful radio source **Virgo A**. Long-exposure photographs show a jet of luminous gas being shot out of M87, as though the galaxy has suffered some violent event. Astronomers think that the activity in M87 is due to a massive black hole at its center that ejects gas along its axis of rotation, accounting for the visible jet.

The Virgo Cluster is of particular interest to astronomers because it is the nearest large cluster of galaxies to us. Most galaxies, perhaps all, are grouped together in clusters of various sizes. Our own Galaxy is a member of a cluster of fifty or more members called the Local Group, and according to some astronomers, the Local Group is a member of a so-called supercluster centered on the Virgo Cluster. The distance of the Virgo Cluster has been measured by the Hubble Space Telescope as 55 million light years away. At this distance, none of the galaxies appears large or bright, but a number of them are within range of small telescopes. In addition to M87, look for **M49**, an 8th magnitude elliptical galaxy; **M60**, a 9th magnitude elliptical galaxy; and **M84** and **M86**, a pair of 9th magnitude elliptical galaxies.

Another galaxy of note in Virgo is found on the constellation's southern border with Corvus. This is **M104**, an 8th magnitude spiral galaxy that is not a member of the Virgo Cluster but is closer to us, 30 million light years away. We see M104 edge-on, so although it is a spiral, it appears elliptical through small telescopes. It is known as the **Sombrero Galaxy**, because it resembles a wide-brimmed hat in long-exposure photographs, but do not expect to see it as anything more than an elongated smudge through a small telescope.





June

KEY STARS

Arcturus sparkles overhead as the sky darkens on June evenings. Spica is still prominent in the southwest, although Regulus and the stars of Leo are closer to the western horizon and vanish before midnight. In the north, the Big Dipper stands on its handle. In the south are Antares and the stars of Scorpius, brushing the horizon for observers in high northern latitudes but well displayed for those farther south. Above Antares is the sparse region occupied by the large constellations Ophiuchus and Serpens. Becoming prominent in the eastern sky are Vega, Deneb, and Altair, the stars of the Summer Triangle.

The planets this month

Venus

- 2020 Unobservable for most of the month as it moves between Earth and Sun (inferior conjunction is on June 3). Begins to emerge into the eastern dawn twilight by month's end.
- 2021 Emerges into the evening sky by the end of the month for southerly observers, low in the west at mag. -3.9.
- 2022 Low in the eastern morning twilight throughout the month at mag. -4.0.
- 2023 Dominates the western evening sky at mag. -4.4. Greatest elongation (maximum separation from the Sun) of 45° is on June 4 when the planet appears at half phase through telescopes. Forms a pair with much fainter Mars (mag. 1.7) in the second half of the month.
- 2024 Unobservable behind the Sun. At superior conjunction on June 4.

Mars

- 2020 A morning object low in the southeast, moving from Aquarius into southern Pisces and brightening from mag. 0.0 to -0.5, but very low for more northerly observers.
- 2021 Low in the western evening sky after sunset at mag. 1.8, becoming lost in twilight during the month.
- 2022 In the eastern dawn sky at mag. 0.6, but remaining difficult to see from more northerly latitudes. Starts the month close to brilliant Jupiter (mag. -2.3).
- 2023 Low in the western evening sky after sunset, but swamped by twilight as seen from more northerly latitudes. Ends the month near dazzling Venus.
- 2024 Low in the eastern dawn sky during the month at mag. 1.0, but difficult to see from more northerly latitudes.

Jupiter

- 2020 Visible from late evening until dawn in Sagittarius, reaching a brilliant mag. -2.7 by month's end. Fainter Saturn remains to its left.
- 2021 A morning object in Aquarius at a prominent mag. -2.4, although low as seen from more northerly latitudes.
- 2022 A morning object low in the east in southern Pisces at mag. -2.3, but lost in the summer twilight from more northerly latitudes.
- 2023 Low in the eastern dawn sky throughout the month at mag. -2.1. Difficult to see from northerly latitudes.
- 2024 Emerges into the eastern dawn sky before sunrise during the month at mag. -2.0 but swamped in summer twilight as seen from the most northerly latitudes.

Saturn

- 2020 Visible from late evening until dawn in Capricornus, near the border with Sagittarius, brightening to mag. 0.2 by month's end. Brilliant Jupiter remains to its right. Rings tilted Earthward at 21°.
- 2021 Visible from late evening until dawn in Capricornus at mag. 0.5. Rings tilted Earthward at 17°.
- 2022 A morning object in Capricornus, near the border with Aquarius, at mag. 0.6. Rings tilted Earthward at 12°.
- 2023 A morning object in Aquarius at mag. 0.9. Rings tilted Earthward at 7°.
- 2024 A morning object in Aquarius at mag. 1.1. Rings tilted Earthward at 2°, appearing as only a slender line.

Eclipses

Sun

- 2020 June 21. Annular solar eclipse, visible from northeast Africa, the southern Arabian peninsula, south Asia, China, and the Pacific Ocean; maximum duration 38s. A partial eclipse is visible from east and North Africa, southeast Europe, the Middle East, south and east Asia, and the Pacific Ocean.
- 2021 June 10. Annular solar eclipse, visible from Canada, Greenland, and the Arctic Ocean; maximum duration 3m, 51s. A partial eclipse is visible across northeastern North America, Europe except the southeast, and Russia.

Hercules

Two giants stand head to head in the June sky. Hercules represents the Greek hero who undertook twelve labors on the orders of King Eurystheus of Mycenae. The other figure is Ophiuchus, a man entwined by a serpent. Both constellations are large—Hercules is the fifth-largest in the sky and Ophiuchus the eleventh-largest—but neither is particularly prominent. Hercules contains no star brighter than 3rd magnitude and consequently is not easy to find. Look for him between the bright stars Vega and Arcturus.

Hercules appears upside-down in the sky. His head lies in the south of the constellation, near the border with Ophiuchus, and is marked by the star **Alpha** (α) **Herculis**, known as **Rasalgethi**, from the Arabic, meaning "kneeler's head." Alpha Herculis is usually classified as a red giant, but sometimes it is put among the supergiants. As with most giant stars, it changes in size, varying in brightness as it does so. It fluctuates between 3rd and 4th magnitude with no set period.

Alpha Herculis is one of the largest stars known, but as with all such distended stars, the exact dimensions remain uncertain. At its distance of about 360 light years, it must emit as much light as 1,000 Suns and have a diameter a few hundred times that of the Sun, so huge that it could easily engulf the orbit of Mars.

Alpha Herculis is a glorious but tight double star for small telescopes. Its close companion of 5th magnitude appears greenish by contrast with the burnished copper color of Alpha Herculis. The two stars form a slow-moving binary, orbiting every few thousand years.

Hercules is a good hunting ground for double stars. Start with **Delta** (δ) **Herculis**, an unrelated duo of 3rd and 8th magnitudes. Another unrelated pair is **Kappa** (κ) **Herculis**, a 5th magnitude yellow giant with a wide 6th magnitude orange giant companion. **Rho** (ρ) **Herculis** is a 5th magnitude pair for

small telescopes, both white in color. Look next at **95 Hercules**, an attractive pair of 5th magnitude stars appearing silver and gold in color like Christmas tree decorations. Finally, do not miss **100 Hercules**, a matched pair of 6th magnitude white stars, easily divisible by small telescopes.

The most distinctive part of Hercules is the “**keystone**” representing his pelvis, formed by four stars: Zeta (ζ), Eta (η), Epsilon (ϵ), and Pi (π) Hercules. Between Eta and Zeta Hercules lies one of the showpieces of the heavens, the great globular cluster **M13**, a city of 300,000 stars or more, compressed into a ball 100 light years across and lying 23,000 light years away.

M13 is one of 150 globular clusters that are scattered in a halo around our Galaxy. It is the brightest globular cluster in northern skies, glimpsed by the naked eye on clear nights as a luminous patch resembling a faint star out of focus. Binoculars show it as a mysterious glowing ball, covering about one-third the diameter of the full Moon and with two faint stars standing like sentinels on either side. Note how its brightness increases toward the center, where the stars are most crowded. The brightest stars in the cluster are giants, emitting the light of 1,000 Suns. Telescopes of 100 mm (4 inches) aperture and above show those giants superimposed on the general background glow, giving the cluster an amazing granular appearance at high magnification.

Hercules contains a second globular cluster, **M92**, which is smaller than M13 and about half the brightness but still easily visible through binoculars. M92 has a brighter center than M13, because its stars are more densely packed. This gives it a more stellar appearance than M13, and M92 can at first be mistaken for a star. M92 is nearly 30,000 light years away, farther than M13.

Ophiuchus

One of the lesser-known constellations is Ophiuchus, which straddles the celestial equator between Hercules and Scorpius. Ophiuchus represents the Greek god of medicine, Asclepius

(the Roman Aesculapius). His symbol was the snake, and in the sky Ophiuchus is inextricably linked with a serpent, in the form of the constellation Serpens, which is visualized as being wrapped around him. Ophiuchus divides Serpens into two, an arrangement that is unique among the constellations. Serpens Caput, the serpent's head, lies on the right of Ophiuchus as we look at it, while Serpens Cauda, the tail, is on the left. Nevertheless, the two halves of Serpens are regarded as one constellation. This celestial triptych of Ophiuchus and the two halves of Serpens can be seen in the south during summer nights.

Ophiuchus contains a number of globular clusters, the brightest being **M10**, **M12**, and **M62**. All three, of 7th magnitude, are visible in binoculars, but they pale in comparison to M13 in Hercules. Far more appealing is the open cluster **IC 4665**, a scattering of twenty or so stars of 7th magnitude and fainter, in the same field as the orange giant Beta (β) Ophiuchi. This cluster is ideal for binoculars because of its large apparent size, bigger than the full Moon.

For an attractive double star, turn a small telescope on **36 Ophiuchi** in the constellation's southern reaches and see a pair of matching 5th magnitude orange dwarf stars. Then look farther north to **70 Ophiuchi**, a beautiful golden-yellow and orange duo, magnitudes 4.2 and 6.2, that orbit each other every eighty-eight years. The stars are currently moving apart as seen from Earth and are divisible in the smallest telescopes. It should be interesting to watch their separation increase year by year, reaching a maximum around 2025. No observer should miss 70 Ophiuchi, one of the most famous double stars in the sky.

On the constellation's border with Scorpius, just north of Antares, lies an outstanding multiple star for small apertures, **Rho (ρ) Ophiuchi**. Low magnification shows a “V”-shaped grouping consisting of a 5th magnitude star at the apex, accompanied by two stars of 7th magnitude. High powers show that the star at the triangle's apex is double, consisting of a tight pair of 5th and 6th magnitudes. In long-exposure photographs, this whole area is enveloped in a faint haze of nebulosity that extends southward to Antares.

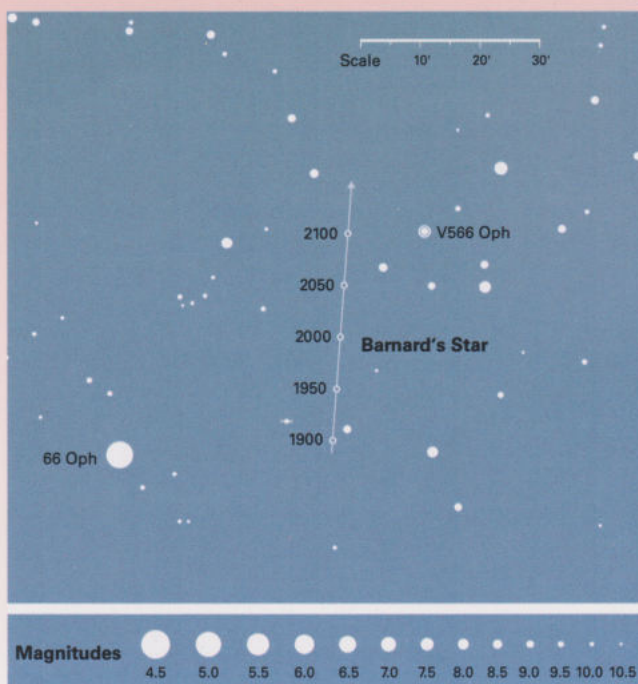
Barnard's Star

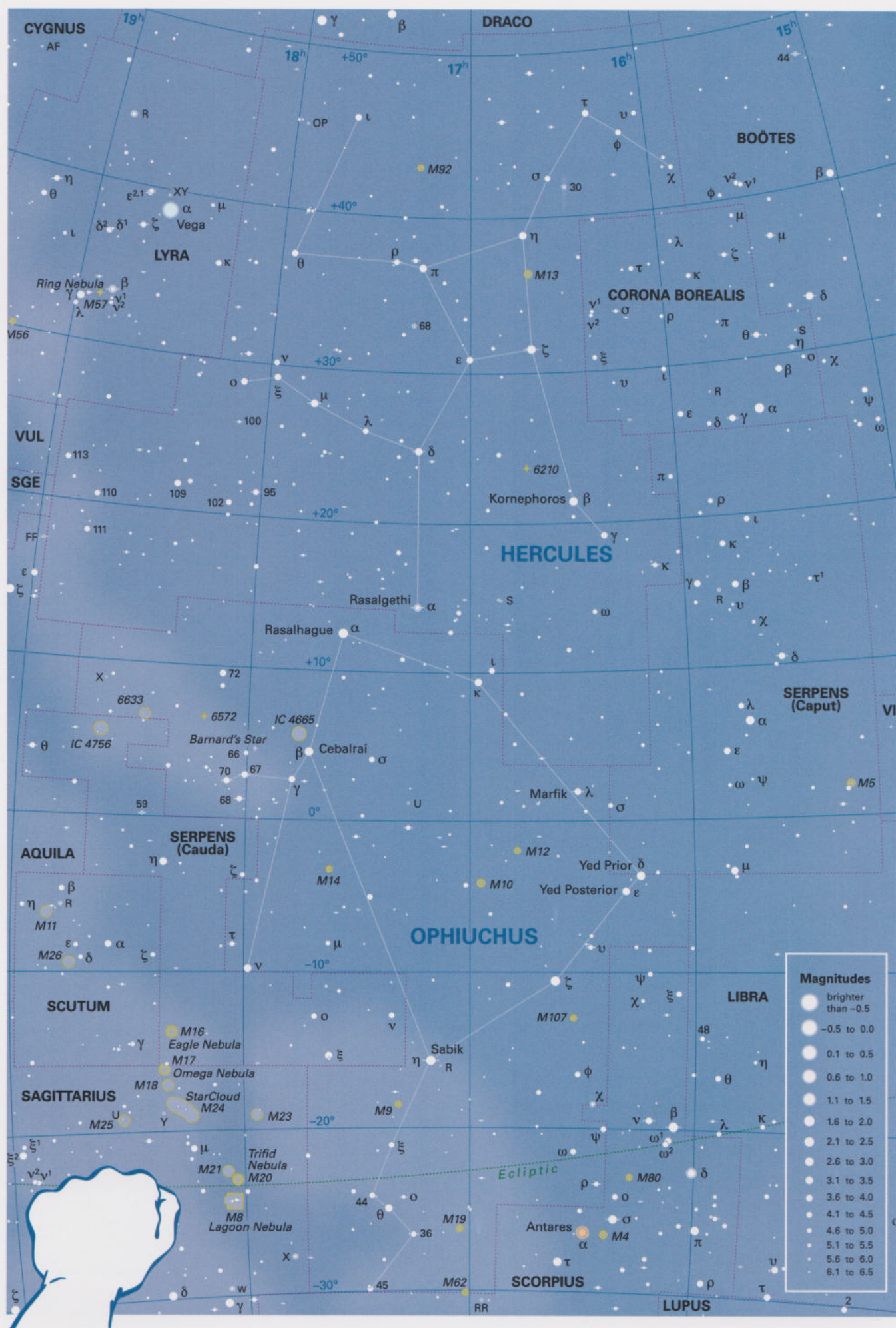
Oddly enough, the most celebrated star in Ophiuchus is not visible to the naked eye. Nor is it easy to find in small telescopes. It is worth hunting for, because it is the second-closest star to the Sun and the fastest-moving star in our skies.

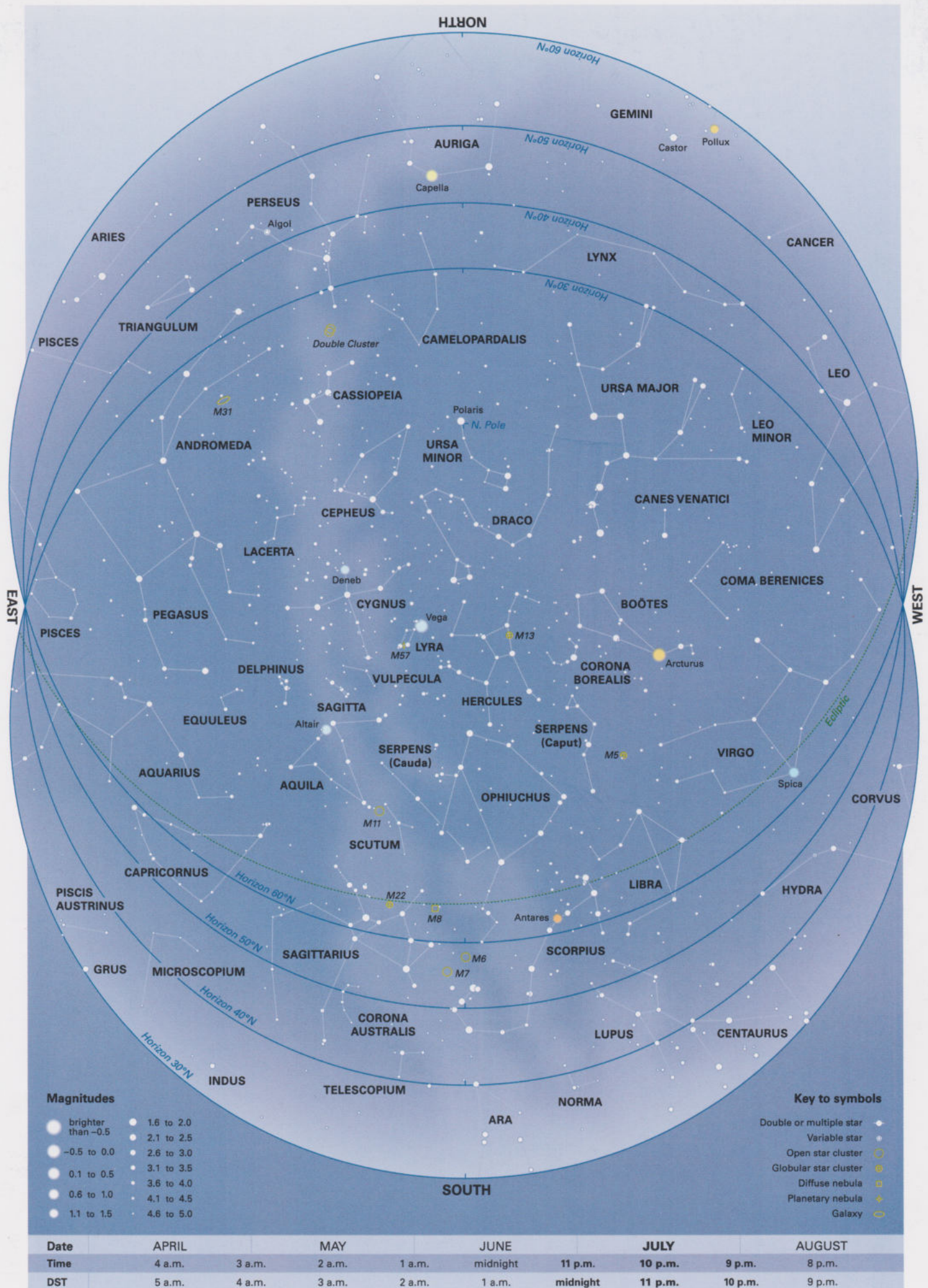
It is Barnard's Star, a red dwarf of magnitude 9.5, lying 5.9 light years away. This faint star is named after American astronomer Edward Emerson Barnard, who noticed in 1916 that it had changed markedly in position in two photographs taken twenty-two years apart. All stars are on the move, but most move almost imperceptibly. Barnard's Star has the fastest movement across the sky of any star, crossing the apparent diameter of the full Moon in 180 years.

In addition to its movement across the sky, Barnard's Star is approaching the Sun. It will reach its minimum distance from us in 11,800 CE, when it will be 3.8 light years away, closer than Alpha Centauri is today. Yet it is so feeble that even then it will appear as only magnitude 8.5. Barnard's Star has a mass about 15 percent that of the Sun, and it is 2,300 times fainter than the Sun.

Barnard's Star lies to the left of Beta (β) Ophiuchi, near the 5th magnitude star 66 Ophiuchi, which is slightly variable. The chart shows how rapidly the star's position moves. Observe it over a period of years so that you can detect the motion of this runaway star.







KEY STARS

Brilliant blue-white Vega sparkles like a sapphire overhead, leading the Summer Triangle of stars across the July sky. In the southwest, Arcturus is sinking and Spica is about to vanish below the horizon. Antares can still be seen low in the southwest. The southern star-fields of Scorpius and Sagittarius are displayed at their best in the evening sky this month. Capella twinkles low on the northern horizon, as seen from high northerly latitudes. On the eastern horizon, the Square of Pegasus heralds the arrival of the stars of autumn.

The planets this month

Venus

- 2020 Emerges into the eastern dawn sky during the month at a brilliant mag. -4.5 , although remaining low for more northerly observers.
- 2021 Low in the western evening sky at mag. -3.9 throughout the month, remaining lost in twilight for more northerly observers. Passes one Moon diameter from much fainter Mars (mag. 1.8) on July 12–13.
- 2022 Low in the eastern dawn sky at mag. -3.9 , becoming lost in twilight from all but the most southerly latitudes.
- 2023 Starts the month low in the western evening sky at a brilliant mag. -4.5 , appearing as a crescent through small telescopes, but rapidly becomes swamped by twilight as its separation from the Sun decreases.
- 2024 Too close to the Sun for observation all month.

Mars

- 2020 In the southeastern morning sky in southern Pisces, brightening from mag. -0.5 to -1.1 .
- 2021 Low in the western evening sky and lost in twilight for all but the most southerly observers. Lies one Moon diameter from much brighter Venus on July 12–13.
- 2022 A morning object in the eastern sky, brightening to mag. 0.2 by month's end, but remains embedded in summer twilight for more northerly observers. Passes from Pisces into Aries in the second week of July.
- 2023 Low in the western sky after sunset at the start of the month at mag. 1.7, above brilliant Venus, but rapidly becomes lost in evening twilight from all but the most southerly latitudes.
- 2024 In the eastern dawn sky at mag. 0.9, but remains low in the summer twilight as seen from more northerly latitudes.

Jupiter

- 2020 Prominent all night in Sagittarius. At opposition (south at midnight) on July 14, 619 million km (385 million miles) from Earth, when it reaches mag. -2.8 , almost as bright as it can ever become. Fainter Saturn, which is at opposition a week later, lies to its left.
- 2021 Visible from late evening to dawn in Aquarius at a brilliant mag. -2.7 .
- 2022 Visible from late evening until dawn in southern Pisces and brightening from mag. -2.4 to -2.7 .
- 2023 In the eastern morning sky in Aries at mag. -2.3 , but remaining low from more northerly latitudes.
- 2024 In the eastern dawn sky throughout the month at mag. -2.0 , but remaining low as seen from northerly latitudes. Approaches fainter Mars (mag. 0.9) at month's end.

Saturn

- 2020 Visible all night on the border between Capricornus and Sagittarius. At opposition (south at midnight) on July 20, 1.346 billion km (836 million miles) from Earth, at mag. 0.1. Brilliant Jupiter, which is at opposition a week earlier, lies to its right. Rings tilted Earthward at 22° .
- 2021 Visible for most of the night in Capricornus at mag. 0.3. Rings tilted Earthward at 18° .
- 2022 Visible from late evening until dawn in Capricornus at mag. 0.5. Rings tilted Earthward at 13° .
- 2023 Visible from before midnight until dawn in Aquarius at mag. 0.7. Rings tilted Earthward at 8° .
- 2024 Visible from late evening until dawn in Aquarius at mag. 1.0. Rings tilted Earthward at 2° , appearing as only a slender line.

Lyra

Overhead this month lies the compact and distinctive constellation of Lyra, the Lyre, which represents the harp of the Greek bard Orpheus. According to legend, Hermes made the harp from a tortoise shell and gave it to his half-brother Apollo. In turn, Apollo passed the harp to Orpheus, who could charm wild beasts and even trees with his musical skill. This ability was particularly valuable when Orpheus entered the fearful Underworld to plead for the return of his dead wife, Eurydice.

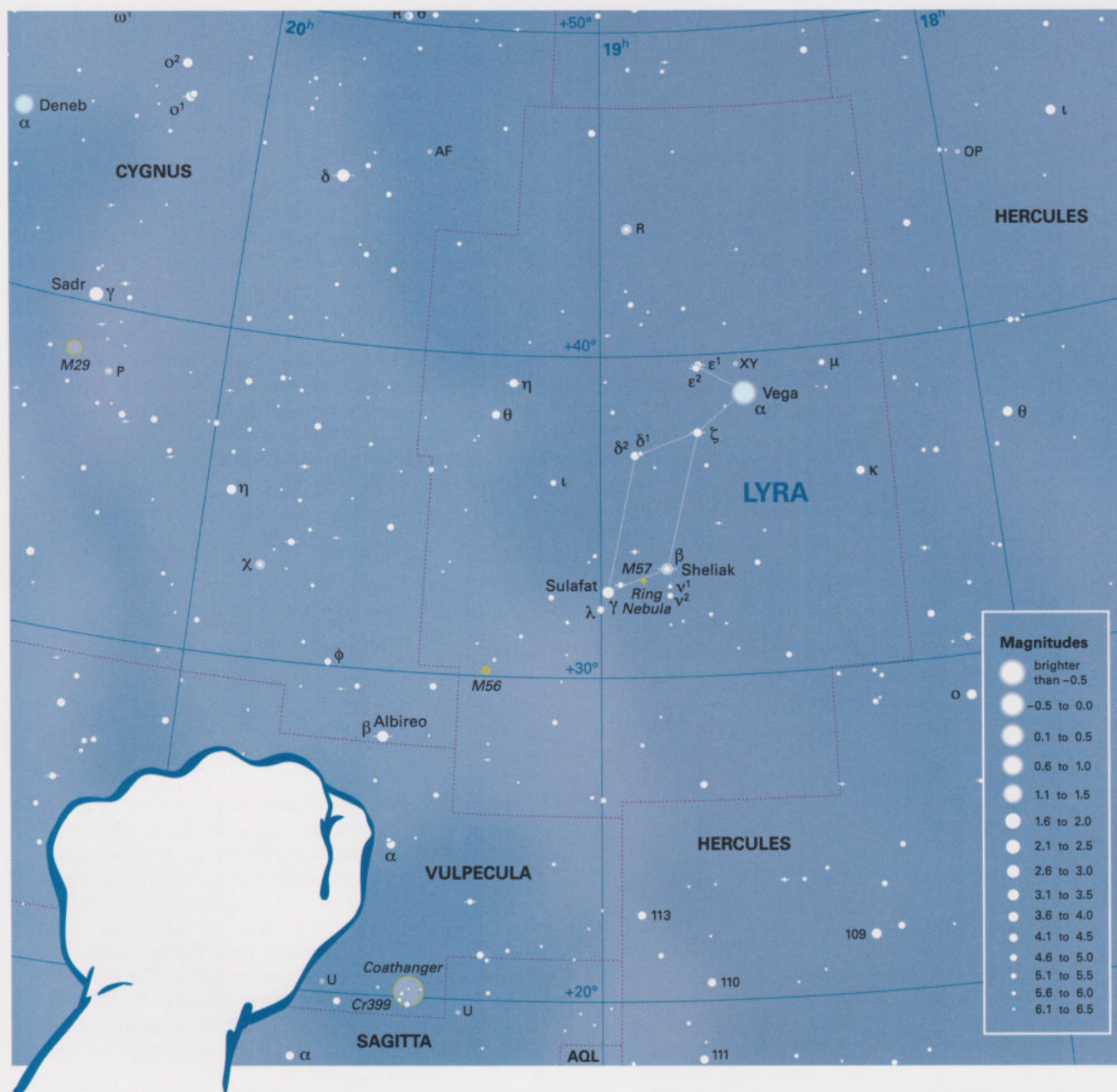
Hades, god of the Underworld, was so moved by the music of Orpheus that he agreed to release Eurydice to the land of the living, under the condition that Orpheus did not look back at her as he led her to the upper world. But just before they emerged into daylight, Orpheus glanced to be sure that she was following, and he lost her forever. Thereafter he roamed the world in sorrow, playing his harp plaintively. After Orpheus died, his harp was placed in the heavens in commemoration of his musical gifts.

The constellation has also been identified as an eagle or a vulture, often depicted on early star maps carrying the harp. Whatever your interpretation of Lyra, it has a rich stock of celestial attractions to charm astronomers.

Lyra is easily located by its brightest star Alpha (α) Lyrae, better known as **Vega**, the fifth-brightest star in the sky. Vega's name comes from the Arabic, meaning "swooping eagle," for the Arabs were among those who visualized the constellation as an eagle. Vega is a blue-white star of magnitude 0.03, lying 25 light years away. It has a mass just over twice that of our Sun and gives out fifty times as much light as the Sun. Astronomers have discovered that Vega is surrounded by a disk of cold, dark dust that is forming into a system of planets—another solar system. Vega is much younger than the Sun, with an age of only about 450 million years. Perhaps, in billions of years, life will evolve on one of those planets that are now forming around Vega.

Near Vega, binoculars or even sharp eyesight shows a wide 5th magnitude double star, **Epsilon (ϵ) Lyrae**, which has a delightful surprise awaiting telescope users. Both stars are double, forming a spectacular stellar quadruplet known as the **Double Double**.

Epsilon-1 Lyrae consists of two stars of magnitudes 5.0 and 6.1 orbiting every 1,750 years or so. Currently they are closing together and will continue to do so throughout the twenty-first century, although only slowly. The current separation is 2.3 arc seconds. Stars with such separations should in theory be divisible by an aperture of 50 mm (2 inches), but the brightness difference means that at least 60 mm (2.4 inches) will be required.



Epsilon-2 Lyrae consists of stars of magnitudes 5.1 and 5.4, whose orbit lasts over 700 years. Their separation is currently about the same as that of Epsilon-1, 2.4 arc seconds, and they are difficult to split in 50 mm (2 inch) apertures. But whatever your telescope, do not miss this showpiece object, the finest quadruple star in the sky.

Epsilon Lyrae is not the only double star in this constellation with a surprise up its sleeve. Look at **Beta (β) Lyrae**, an attractive coupling of a cream primary with a 7th magnitude blue companion, easily separated by small telescopes. But the primary star is a complex eclipsing binary that varies between magnitudes 3.3 and 4.4 every thirteen days. Compare its brightness with that of Gamma (γ) Lyrae, constant at magnitude 3.2.

Astronomers have struggled for decades to understand the curious primary of Beta Lyrae, whose period of variation is gradually lengthening. The answer has come from carefully studying the star's light through spectroscopes. The two eclipsing stars are so close together (closer than Mercury is to the Sun) that each is distorted into an egg shape by the other's gravity. Gas flows between the stars, some of it spiraling away into space. When you look at Beta Lyrae, try to imagine the turbulent activity taking place there, unseen by the human eye.

Another double variable is **Delta (δ) Lyrae**, an easy binocular duo consisting of a 4th magnitude red giant star that is slightly variable and a blue-white star of magnitude 5.6. The two lie at different distances from us and are unrelated. Look also at **Zeta (ζ) Lyrae**, a binocular pair of magnitudes 4.4 and 5.7.

Between Beta and Gamma Lyrae lies another of the treasures of Lyra, the famous **Ring Nebula, M57**, a celestial smoke ring thrown off by a dying star about 2,000 light years away. M57 is a type of object known as a planetary nebula, not because it has anything to do with planets but because it shows a rounded disk like a planet when viewed through a telescope. Such an object is believed to be formed when a star like the Sun reaches the end of its life. After swelling up into a red giant, the star sloughs off its distended outer layers to form a planetary nebula, leaving the core as a faint white dwarf. Observations by the Hubble Space Telescope have revealed that the Ring Nebula is not a ring but a cylinder of gas that we happen to view end-on.

Small telescopes show M57 as a faint hazy spot, larger than the disk of Jupiter. Apertures of at least 100 mm (4 inches) are needed to discern its ring shape. Its central star, of 15th magnitude, is too faint for amateur telescopes. M57 is most impressive in long-exposure photographs.

Vulpecula

Adjoining Lyra is Vulpecula, the Fox, a little-known constellation well worth an introduction. Like its southerly neighbor Sagitta, Vulpecula straddles a rich area of the Milky Way and is a good hunting ground for novae. The constellation was placed in the sky in 1690 by the Polish astronomer Johannes Hevelius under the title of Vulpecula cum Anser, the Fox and Goose, which has since been shortened. Hevelius said that he placed a fox here to be close to two other predatory animals, the vulture (Lyra) and the eagle (Aquila). Its brightest star, **Alpha (α) Vulpeculae**, magnitude 4.4, has an unrelated companion of 6th magnitude easily visible through binoculars.

Vulpecula achieved unexpected fame in 1967 when radio astronomers in Cambridge, England, discovered the first of the flashing radio stars called pulsars south of Alpha Vulpeculae. Pulsars are thought to be the highly condensed cores of stars that have exploded as supernovae. Like most pulsars, this one is so faint that it is practically invisible.

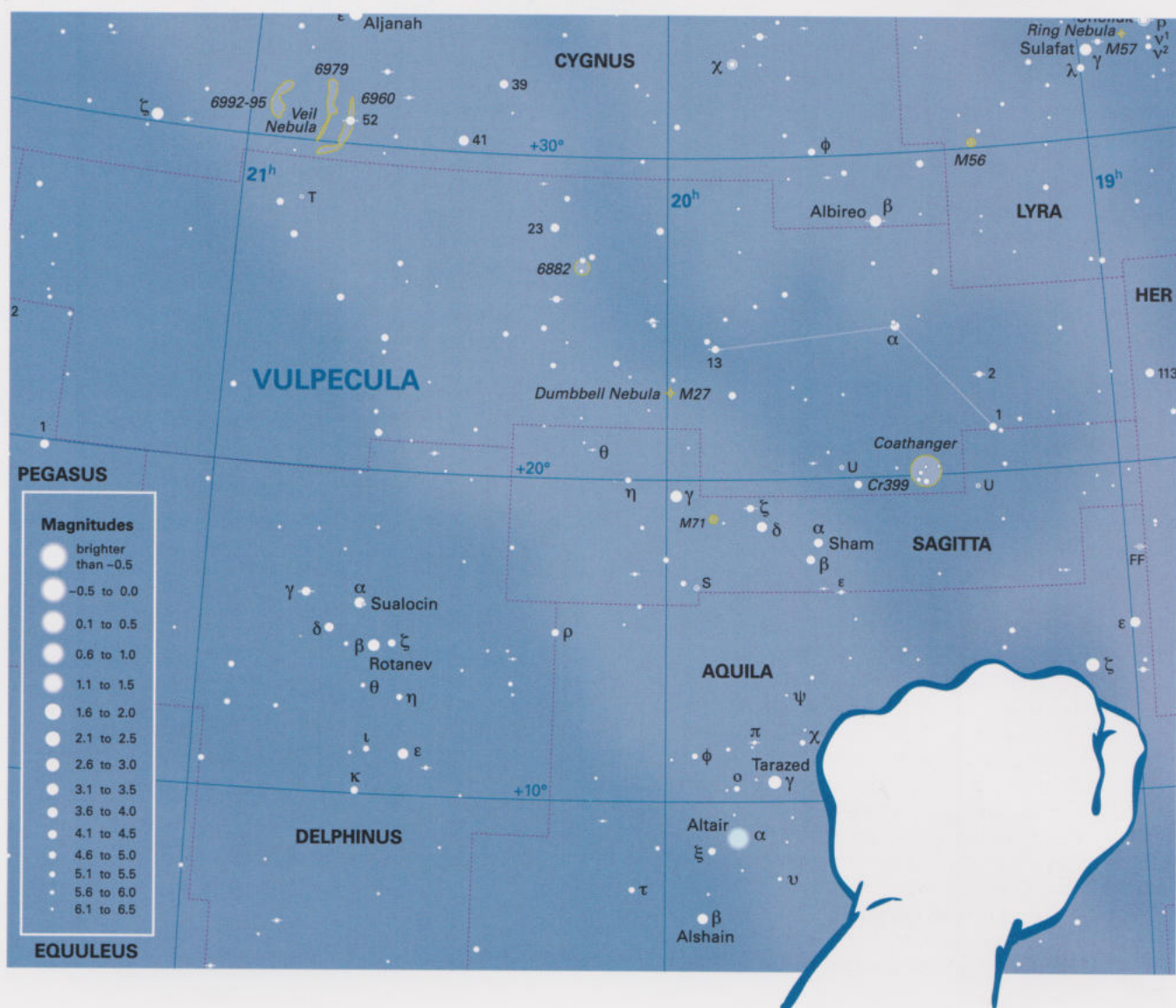
Close to the border with Sagitta lies one of the oddest-looking star groupings in the sky, sometimes known as **Brocchi's Cluster** or **Collinder 399** but more commonly called the **Coathanger** because of its distinctive shape. Its main feature is an almost perfectly straight line of six stars. From its center protrudes a curving hook of four more stars, completing the coathanger shape. The ten stars of the Coathanger are from 5th to 7th magnitude and the whole object is $1\frac{1}{2}^\circ$ long, making it an ideal binocular sight.

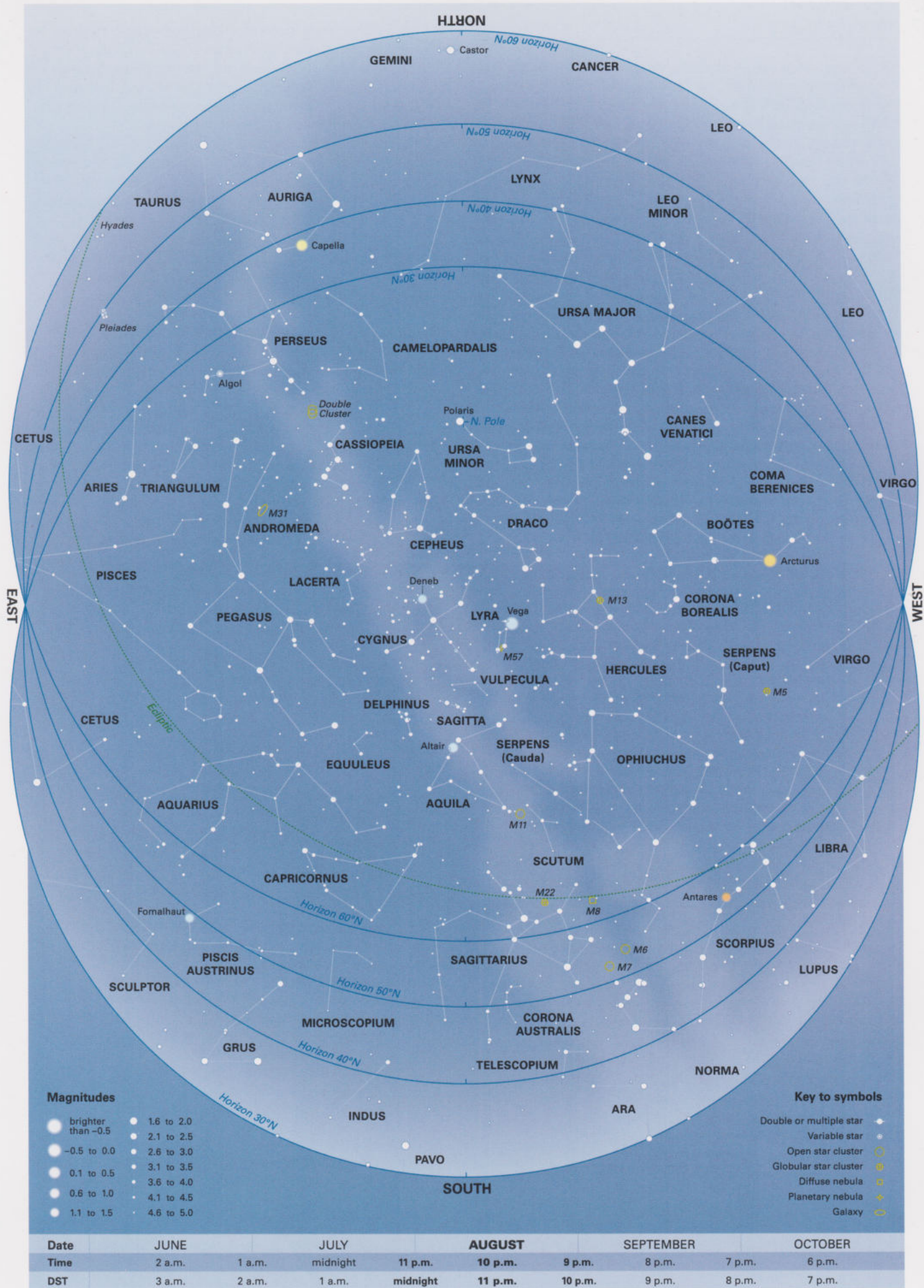
The Coathanger is not a true cluster, because its stars lie at a wide range of distances—from about 240 light years to around 2,000 light years—and are moving through space in different directions. The stars cannot be related, and they lie in the same line of sight only by coincidence. Despite this, the Coathanger remains a delightful surprise.

From the Coathanger, turn your binoculars to the best-known object in Vulpecula, **M27**, known as the **Dumbbell Nebula**. M27 is a planetary nebula, a shell of gas thrown off by a dying star, like the Ring Nebula in Lyra. But the Ring Nebula and the Dumbbell have noticeably different appearances.

Whereas many planetary nebulae are difficult to spot because they are small, the Dumbbell can be missed because it is unexpectedly large. At 8th magnitude the Dumbbell is bright enough to show up in binoculars as a smudgy patch even under indifferent sky conditions. It is elongated, with a maximum diameter about a quarter that of the full Moon, eight times larger than the Ring Nebula. Having a favorable combination of size and brightness, M27 is the most conspicuous of all planetary nebulae, at least in small instruments.

Seen through a telescope, the Dumbbell is greenish in color. It gets its name from its double-lobed shape in telescopes, reminiscent of an hourglass, or perhaps a figure eight, in distinct contrast to the rounded shape of the Ring Nebula. Its central star, the white dwarf that has shed its outer layers to form the nebula, is of 14th magnitude, too faint for small telescopes. The Dumbbell lies about 1,400 light years away, among the closest planetary nebulae to us.





August

KEY STARS

The Summer Triangle of Vega, Deneb, and Altair stands high above as the sky darkens on August evenings. The ruddy glow of Arcturus is sinking toward the western horizon, and the stars of the Big Dipper dip low in the northwest. Antares still glints in the southwest for those below latitude 50° north, while in the southeast lonely Fomalhaut climbs above the horizon in its barren part of the sky. In the east rises the Square of Pegasus, followed by the stars of Andromeda. Capella is above the northern horizon for observers north of latitude 40°.

The planets this month

Venus

- 2020 Brilliant but low in the eastern dawn sky throughout the month at mag. -4.3 . Greatest elongation (maximum separation) from the Sun of 46° is on August 13, when the planet appears at half phase through telescopes.
- 2021 Low in the west at mag. -4.0 and engulfed in evening twilight for all but the most southerly observers.
- 2022 Lost in the eastern dawn twilight throughout the month.
- 2023 Unobservable as it moves between Earth and Sun. Inferior conjunction is on August 13.
- 2024 Too close to the Sun for observation throughout the month.

Mars

- 2020 Visible from late evening to dawn in southern Pisces and brightening rapidly from mag. -1.1 to -1.8 .
- 2021 Too close to the Sun for observation throughout the month.
- 2022 In the eastern morning sky, passing between the Pleiades and Hyades star clusters in Taurus in the second half of August and brightening to mag. -0.1 by month's end.
- 2023 Lost in the western evening twilight throughout the month.
- 2024 A morning object in Taurus at mag. 0.8 , moving rapidly toward the border with Gemini. Passes brilliant Jupiter (mag. -2.2) at mid-month.

Jupiter

- 2020 A prominent evening object in Sagittarius at mag. -2.6 . Fainter Saturn, mag. 0.2 , lies to its left.
- 2021 Prominent all night on the border between Aquarius and Capricornus. At opposition (south at midnight) on August 20, 600 million km (373 million miles) from Earth, at a dazzling mag. -2.9 , as bright as it ever gets.
- 2022 Prominent for most of the night in southern Pisces at a brilliant mag. -2.8 .
- 2023 A brilliant morning object in Aries at mag. -2.5 .
- 2024 A morning object in Taurus at mag. -2.2 . Passes less than one Moon diameter from fainter Mars (mag. 0.8) on March 14–15.

Saturn

- 2020 Visible all evening until after midnight in Sagittarius, near the border with Capricornus, at mag. 0.2 . Brilliant Jupiter (mag. -2.6) remains to its right. Rings tilted Earthward at 22°.
- 2021 Visible all night in Capricornus at mag. 0.2 . At opposition (south at midnight) on August 2, 1.337 billion km (831 million miles) from Earth. Rings tilted Earthward at 19°.
- 2022 Visible all night in Capricornus at mag. 0.3 . At opposition (south at midnight) on August 14, 1.325 billion km (823 million miles) from Earth. Rings tilted Earthward at 14°.
- 2023 Visible all night in Aquarius. At opposition (south at midnight) on August 27, 1.311 billion km (815 million miles) from Earth, at mag. 0.4 . Rings tilted Earthward at 9°.
- 2024 Visible for most of the night in Aquarius at mag. 0.7 . Rings tilted Earthward at only 3° and difficult to see.

August meteors

Warm summer nights are ideal for meteor observing, and August has the brightest of the year's meteor showers, the **Perseids**. This is the shower when you should begin observing meteors. The Perseids reach a peak around August 12 every year, when up to one meteor per minute may be seen streaking away from the northern part of the constellation Perseus, near the border with Cassiopeia. The radiant does not rise very high until late at night, so do not expect to see many Perseids before midnight. Continue watching into the early morning hours, for the rate of Perseids should increase toward dawn as the radiant climbs higher in the sky. Perseid meteors can be spectacular. They are usually bright, they frequently flare up, and many leave glowing trains. The shower is very broad, so that considerable numbers of Perseids can be seen for over a week before and after the maximum. The Perseid meteors are caused by dust from comet Swift-Tuttle, which has an orbital period of about 135 years; it last appeared in 1992.

Cygnus

Everyone has heard of the Southern Cross, as the southern constellation Crux is called, but there is also a far larger cross in the northern sky. The proper name for this constellation is Cygnus, the Swan, but it is often called the Northern Cross.

The Greeks said that Cygnus represented the swan that the god Zeus transformed into in order to seduce Leda, wife of King Tyndareus of Sparta. On summer nights, Cygnus can be seen flying along the sparkling band of the Milky Way, its long neck outstretched toward the southwest and its stubby wings tipped by the stars Delta (δ) and Epsilon (ϵ) Cygni.

The swan's tail is marked by Alpha (α) Cygni, better known as **Deneb**, a name that comes from the Arabic for "tail." Deneb, of magnitude 1.2, is the faintest of the three stars that make up the **Summer Triangle**. Whereas the other two stars of the Triangle, Vega and Altair, are among the closest stars to the Sun, Deneb lies far off, around 1,400 light years away. It is the most distant 1st magnitude star—and nearly twice as far as Rigel in second place.

To be easily visible to the naked eye over such an immense distance, Deneb must be exceptionally powerful. It is among the most luminous stars, a supergiant with a white-hot surface giving out 50,000 times as much light as the Sun. If Deneb were as close to us as the brightest star, Sirius, it would appear as brilliant as a half Moon and the sky would never be dark when above the horizon.

Even more remarkable is the star **P Cygni**, located near the base of the swan's neck. It is currently of 5th magnitude, but, on two occasions during the seventeenth century, it temporarily brightened fivefold to 3rd magnitude. P Cygni is so massive that it is unstable, throwing off shells of gas at irregular intervals, causing its surges in brightness. It is evolving into a red supergiant and will probably end its life by exploding as a supernova. Although data about such stars are highly uncertain, P Cygni is thought to have a mass of about 50 Suns and to shine as brightly as 100,000 Suns. It lies even farther away than Deneb, among the most distant stars of the Milky Way.

Cygnus is an ideal region to explore on warm summer evenings. Begin by sweeping with binoculars along the star-splashed Milky Way, which is particularly rich in this area. Look for a major division in the Milky Way called the **Cygnus Rift**, caused by a lane of dark dust in the local spiral arm of our Galaxy that blocks starlight from behind. The rift can be traced southward from Cygnus through Aquila and into Ophiuchus, broadening as it approaches us.

Of the star clusters in Cygnus, the best in binoculars is **M39**, a scattered group of twenty or so stars of 7th magnitude and fainter, arranged in a triangular shape. M39 lies about 1,000 light years away, much closer than the background stars of the Milky Way.

Under clear, dark skies, binoculars should show the large, misty shape of the **North America Nebula**, named because of its remarkable resemblance to North America, although its shape is more apparent in long-exposure photographs than through small instruments. The Nebula, also known as **NGC 7000**, lies near the star Xi (ξ) Cygni, and covers four times the width of the Moon. It's so large that only binoculars or wide-angle telescopes can encompass it all.

This immense mass of gas and dust, 50 light years across, appears to lie near the star Deneb. It has been suggested that the North America Nebula and its smaller, fainter companion the **Pelican Nebula** are lit up by Deneb, but the true candidate is now thought to be an even hotter, unnamed star hidden among the nebulosity near the "Florida" region of NGC 7000.

While scanning Cygnus, be sure to look at **Omicron-1 (ο¹) Cygni**, a binocular gem. This orange star, magnitude 3.8, forms a beautiful wide pairing with the turquoise 30 Cygni, one magnitude fainter. Binoculars, if held steadily, will reveal a 7th magnitude blue star closer to Omicron-1 Cygni.

This is an ideal warm-up before turning your gaze upon the queen of double stars, the beautiful **Beta (β) Cygni**, or **Albireo**. (Its name results from a mistranslation and is completely meaningless.) Albireo is easily found, marking the beak of the swan—or, if you prefer, the foot of the cross. The smallest of telescopes, and even binoculars mounted steadily, show that Albireo consists of a glorious pair of amber and blue-green stars, magnitudes 3.1 and 5.1, like a celestial traffic light. These beautifully contrasting colors, similar to those of Omicron-1 Cygni, appear more intense if you put the stars slightly out of focus or if you tap the telescope so that the image vibrates.

Although the two components of Albireo lie at similar distance from us, about 400 light years, it is not certain that they form a true binary. If the fainter star is in orbit around the brighter one, it would probably take over 100,000 years to complete one circuit. Whatever the case, Albireo remains one of the greatest attractions in the sky.

For another celebrated double, look above the crossbar of Cygnus to find **61 Cygni**, a pair of orange stars of 5th and 6th magnitude, easily separated in small telescopes. The two stars orbit each other every 680 years. Considerable historical interest surrounds 61 Cygni; it was the first star to have its distance measured by the technique of parallax. In this technique, a star's position is accurately noted on two occasions six months apart, when the Earth is on opposite sides of its orbit around the Sun. The slight shift in the star's position as seen from the two vantage points reveals how far away the star is through simple geometry. A nearby star will move noticeably, whereas a distant star will hardly move at all.

The observations of 61 Cygni were made by the German astronomer Friedrich Wilhelm Bessel in 1838. He concluded that 61 Cygni is 10.3 light years away, a figure that compares well with the modern value of 11.4 light years. Of the naked-eye stars, only Alpha Centauri, Sirius, and Epsilon Eridani are closer than 61 Cygni.

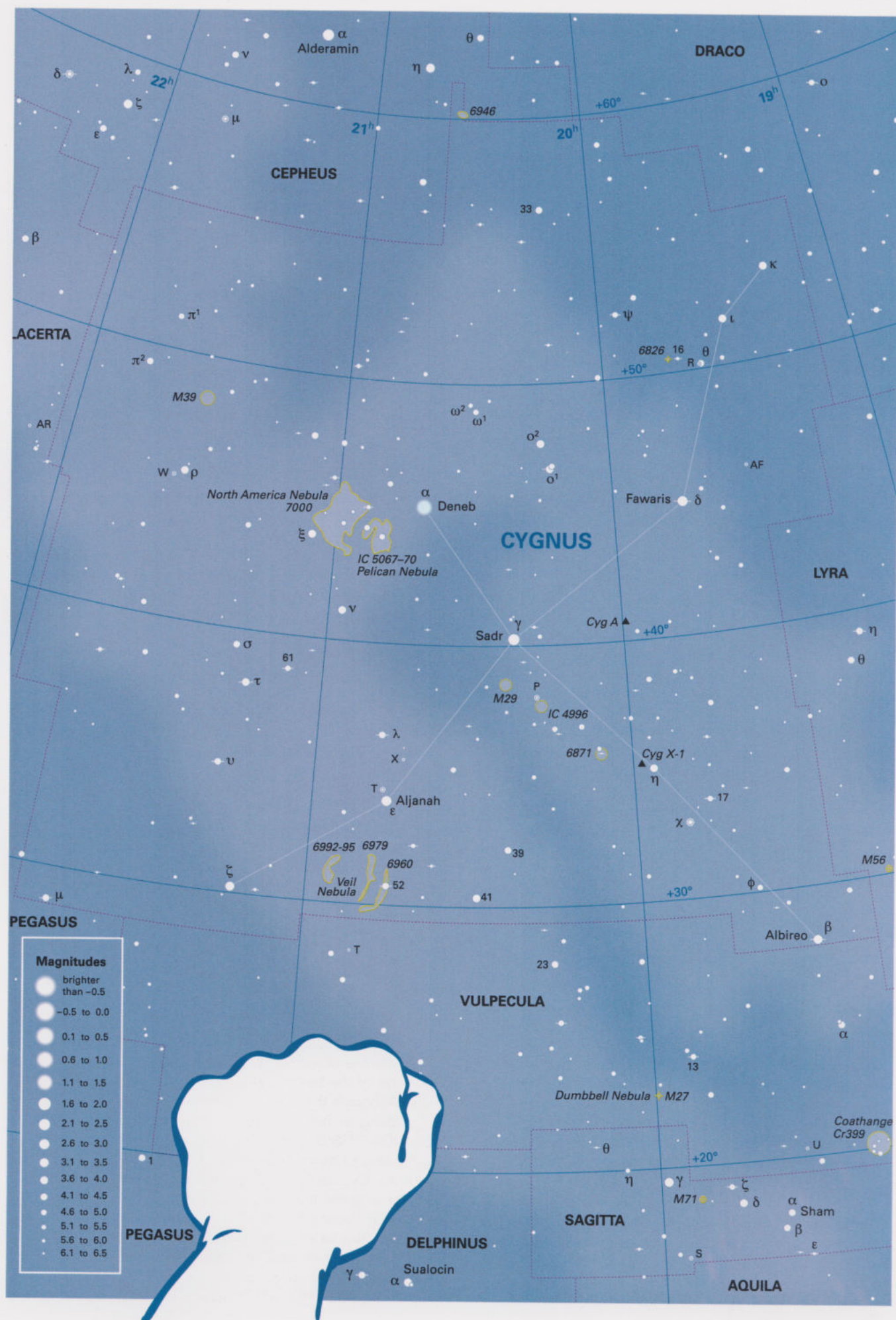
A lesser-known treasure of Cygnus is a remarkable planetary nebula, **NGC 6826**, known as the **Blinking Planetary** because it appears to blink on and off as you look at it and then away. To find it, first locate **16 Cygni**, an attractive duo of 6th magnitude yellow stars easily split by small telescopes. The Blinking Planetary lies less than 1° from this pair, so that both objects will just fit into the same telescopic field of view.

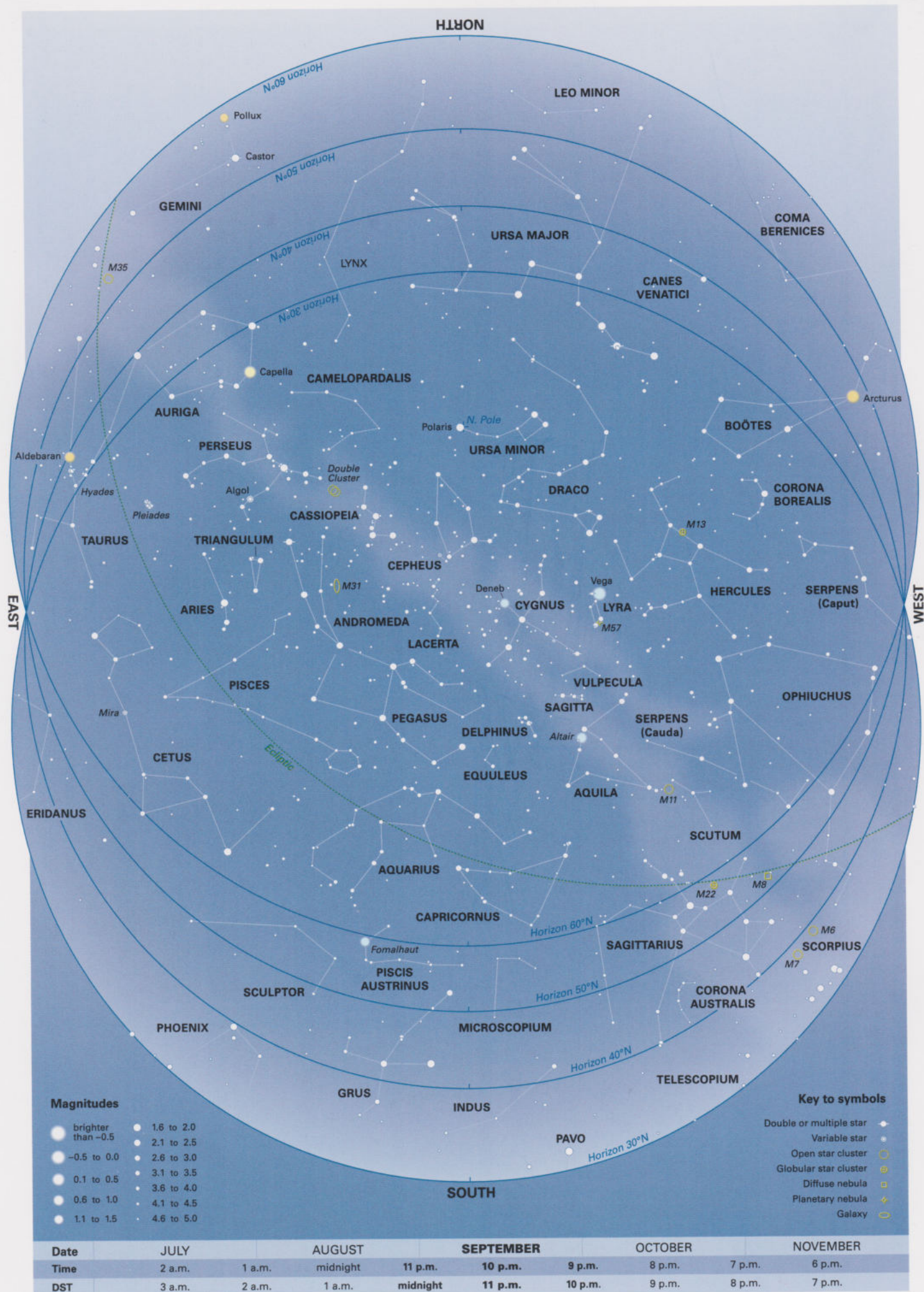
In small telescopes with low magnification, NGC 6826 looks like a fuzzy, faint star. Higher magnification reveals a light-blue disk with a 10th magnitude star at its center, although this central star will probably be beyond the reach of the smallest telescopes. Like any delicate object, the nebula is best seen with averted vision—that is, by looking to one side of it. Alternately looking at the nebula and away again produces the uncanny blinking effect that gives this object its name. The blinking is an optical effect in the observer's eye and does not originate in the nebula itself.

Some of the most amazing objects in Cygnus are beyond the reach of amateur instruments. On the border of Cygnus with Vulpecula lies an enormous loop of gas, the **Veil Nebula**, the twisted wreckage of a star that exploded as a supernova 5,000 years ago. At an estimated distance of 1,400 light years away from us, the supernova would have been bright enough to cast shadows on Earth. The Veil Nebula covers 3° of sky, equivalent to the width of two fingers held at arm's length. The brightest portion of the Veil, **NGC 6992-95**, may just be made out in binoculars under exceptional conditions, but most observers will have to content themselves with studying photographs in books.

Between Gamma (γ) and Delta (δ) Cygni, in one of the wings of the Swan, lies **Cygnus A**, one of the most intense sources of radio noise in the sky. Photographs show that it is a peculiar-looking elliptical galaxy of 15th magnitude, either exploding or undergoing a collision. It lies deep in the Universe, about 750 million light years outside the Milky Way.

Of all the objects in Cygnus, the most bizarre is **Cygnus X-1**, one of the best candidates in the Milky Way for a black hole. Although the black hole is invisible, it gives itself away by sucking in hot gas from a neighboring 9th magnitude star, HDE 226868. Gas falling toward the black hole heats up to millions of degrees, emitting X-rays that are detected by satellites. Cygnus X-1 lies about 6,000 light years away, along the same spiral arm of the Galaxy where the Sun lies. Its position is about a half-degree (one Moon's breadth) from Eta (η) Cygni. Not far away, midway between Eta (η) and Epsilon (ε) Cygni, lies another black hole suspect, a variable X-ray source called V404 Cygni. In this case, the black hole is orbited by a faint orange star, from which gas falls toward the black hole.





September

KEY STARS

The Summer Triangle remains prominent as darkness falls in September skies. Arcturus is vanishing below the northwestern horizon. From the Summer Triangle the stardust trail of the Milky Way leads eastward to Cassiopeia and Perseus, while Capella twinkles brightly in the northeast. The Square of Pegasus is high in the southeast, while below it lies lonely Fomalhaut, just brushing the southern horizon for far-northern observers. In the east Aldebaran and the stars of Taurus appear, heralding the autumn. In the north, the Big Dipper sinks low.

The planets this month

Venus

- 2020 Brilliant but low in the eastern dawn sky throughout the month at mag. -4.1.
- 2021 Brightens to mag. -4.2 by the end of the month, but too low in the western evening twilight to be seen from mid and far northern latitudes.
- 2022 Too close to the Sun for observation throughout the month.
- 2023 Emerges into the eastern dawn sky during the month at a dazzling mag. -4.5.
- 2024 Low in the western sky after sunset at mag. -3.9 as seen from more southerly latitudes, but too low down for observation from mid-northern latitudes and above.

Mars

- 2020 Visible for most of the night in southern Pisces, brightening rapidly from mag. -1.8 to -2.5 as it approaches opposition next month.
- 2021 Unobservable as it moves behind the Sun toward conjunction next month.
- 2022 Visible for most of the night in Taurus, brightening from mag. -0.1 to mag. -0.5. Passes just north of the Hyades star cluster in the first half of the month.
- 2023 Too close to the Sun for observation throughout the month.
- 2024 A morning object at mag. 0.6, moving from Taurus into Gemini in the first week of September.

Jupiter

- 2020 A prominent evening object in Sagittarius at mag. -2.5. Fainter Saturn, mag. 0.4, lies to its left.
- 2021 Prominent for most of the night in Capricornus at a brilliant mag. -2.8.
- 2022 Prominent all night in southern Pisces. At opposition (south at midnight) on September 26, 591 million km (367 million miles) from Earth, at mag. -2.9, as bright as it ever gets.
- 2023 Prominent from late evening until dawn in Aries at mag. -2.7.
- 2024 Prominent from late evening until dawn in Taurus at mag. -2.4.

Saturn

- 2020 An evening object in Sagittarius at mag. 0.4. Brilliant Jupiter (mag. -2.5) remains to its right. Rings tilted Earthward at 23°.

- 2021 Visible all evening until after midnight in Capricornus at mag. 0.4. Rings tilted Earthward at 19°.
- 2022 Visible all evening until after midnight in Capricornus at mag. 0.4. Rings tilted Earthward at 15°.
- 2023 Visible for most of the night in Aquarius at mag. 0.5. Rings tilted Earthward at 10°.
- 2024 Visible all night in Aquarius at mag. 0.6. At opposition (south at midnight) on September 8, 1.295 billion km (805 million miles) from Earth. Rings tilted Earthward at 4° and difficult to see.

Eclipses

Moon

- 2024 September 18. Partial lunar eclipse, maximum 9 percent, visible from Africa, Europe, the Atlantic Ocean, and the Americas except Alaska.

Cassiopeia

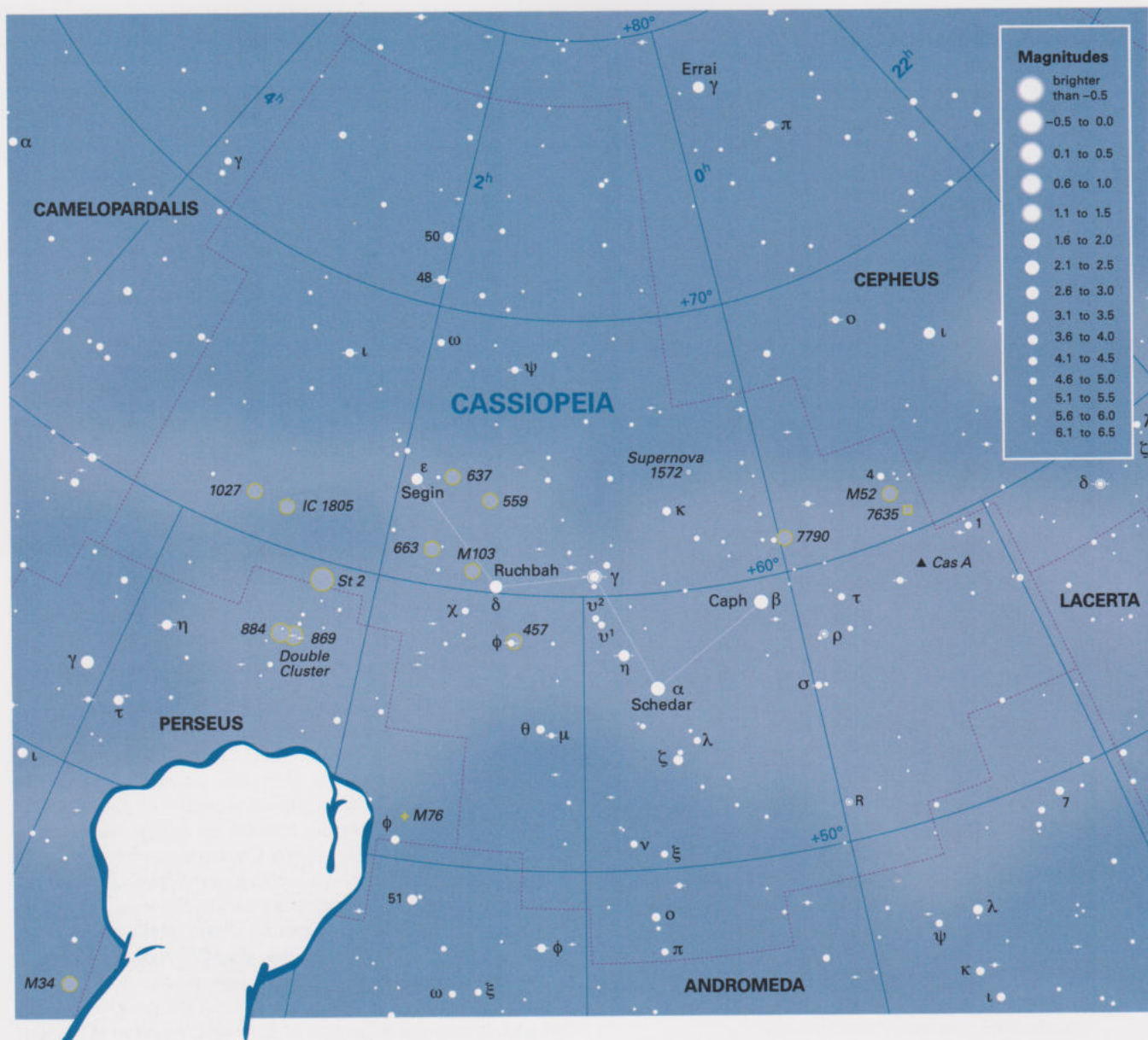
The only married couple among the constellations is Cepheus and Cassiopeia. In Greek mythology, they were King and Queen of Ethiopia, parents of Andromeda. Cassiopeia once boasted that she was more beautiful than the group of sea nymphs called the Nereids. This incurred the wrath of the sea god Poseidon, who sent a terrible monster to ravage the lands of King Cepheus. To save his country, Cepheus was forced to offer his daughter Andromeda as a sacrifice to the monster, although she was rescued from the monster's jaws by Perseus.

Cassiopeia and Cepheus can be found next to each other in the north polar region of the sky. Cassiopeia, the more prominent of the husband-and-wife pair, is depicted sitting in a chair. She circles incongruously around the pole, appearing to hang upside-down for part of the night, a lesson in humility decreed by the Nereids.

Cassiopeia is one of the easiest constellations to recognize because of its distinctive "W" shape. The constellation is easily located, opposite the celestial pole from the Big Dipper. **Gamma** (γ) **Cassiopeiae**, the central star of the "W" shape, is worth keeping an eye out for because of its unpredictable brightness, which has fluctuated between magnitudes 1.6 and 3.0 since early last century, when its variability was first noted. Compare it with neighboring Alpha (α) Cas, magnitude 2.2, and Delta (δ) Cas, magnitude 2.7. Gamma Cassiopeiae is a hot, blue star rotating so rapidly that it throws off rings of gas from its equator, thus producing the changes in brightness. As with all such peculiar stars, data are uncertain, but Gamma Cas is thought to give out as much light as 5,000 Suns and to lie about 550 light years away.

A beautiful double star for small telescopes is **Eta** (η) **Cassiopeiae**, consisting of yellow and reddish stars, magnitudes 3.5 and 7.5. These two stars orbit each other every 480 years. As seen from Earth, they were closest together in 1889 and will continue to move apart until the middle of next century, making the double progressively easier to divide. The pair are only 19 light years away from us, which is relatively close on the interstellar scale.

Lying in a rich part of the Milky Way, Cassiopeia contains numerous open star clusters. Best is **M52**, which is easily found near the border with Cepheus next to a 5th magnitude star, 4 Cassiopeiae. M52 is a fuzzy patch in binoculars that splits into a field of faint stars when seen through a telescope. One member, an 8th magnitude orange giant, is brighter than the rest.



Another cluster visible as a fuzzy patch in binoculars is **M103**. Telescopes show it to have an elongated shape with a spine of stars. The brightest of these, a double star at the northern end of the spine, is not a true member of the cluster but actually lies in the foreground. Nearby is **NGC 663**, a scattered group of stars of varied brightness, larger and more prominent in binoculars than M103.

Look at the sprawling cluster **NGC 457**, whose extended shape has led to various picturesque names such as the Dragonfly Cluster, the ET Cluster, and the Owl Cluster. It can be found next to the 5th magnitude star Phi (φ) Cassiopeiae, which is apparently a true member of the cluster. Since the cluster lies nearly 8,000 light years away, Phi Cas must be an astonishingly luminous supergiant, giving out the light of over 250,000 Suns, five times that of Rigel. As seen through a telescope, the stars of NGC 457 appear to be arranged in chains.

Even more remarkable than Phi is **Rho (ρ) Cassiopeiae**. At first glance it appears unexceptional, but it turns out to be one of the most luminous stars known—a yellow-white supergiant shining as brightly as a half-million Suns and lying 10,000 light years away, perhaps even more. It varies in brightness between 4th and 6th magnitude every two years or so as it pulsates in size.

Two other objects in Cassiopeia deserve mention, although both are beyond the reach of amateur instruments. They are the remains of exploded stars, or supernovae. One, known as **Tycho's Star**, flared up near Kappa (κ) Cassiopeiae in 1572. At its peak it became as bright as Venus, and remained visible to

the naked eye for sixteen months. It was carefully observed by the great Danish astronomer Tycho Brahe. All that is left of Tycho's Star are some faint wisps of gas, visible only with large telescopes, coinciding with a source of radio noise.

The strongest radio source in the sky, **Cassiopeia A**, lies almost 3° south of the cluster M52. Cassiopeia A comprises the remains of another supernova, estimated to have exploded in the late seventeenth century, although it was not visible to the naked eye.

Cepheus

Cepheus, representing the husband of Cassiopeia, lies close to the north celestial pole. In shape it resembles a tower with a steeple. Look beneath the base of the tower to find **Mu (μ) Cephei**, one of the most strongly colored stars in the sky. Sir William Herschel called it the **Garnet Star** because of its deep red tint, which is notable in binoculars and small telescopes. Mu Cephei is a red supergiant with the luminosity of 50,000 Suns. Like many red supergiants and giants, it is erratically variable, fluctuating between magnitudes 3.4 and 5.1. Take a look at this star next time you are out, and try to estimate its brightness by comparing it with Zeta (ζ) Cephei, magnitude 3.4, Epsilon (ε) Cephei, magnitude 4.2, and Lambda (λ) Cephei, magnitude 5.0.

In the middle of the tower of Cepheus lies **Xi (ξ) Cephei**, a tidy double star for small telescopes. Its components are of magnitudes 4.4 and 6.3, and its colors are white and yellow.

The two stars form a genuine binary, orbiting each other every 4,000 years or so. Next try **Beta (β) Cephei**, a magnitude 3.2 star with an 8th magnitude companion, which is difficult to distinguish in the smallest telescopes because of the brightness difference. Beta itself is slightly variable in brightness, by about 0.1 magnitude, which is almost undetectable to the naked eye.

Finally we come to the celebrity of the constellation, **Delta (δ) Cephei**. A small telescope shows it as an easy and attractive double, consisting of a 4th magnitude yellow primary whose magnitude 6.3 companion, bluish in color, is wide enough to be picked out in binoculars if held steadily. But the greatest interest of this star is the primary, a yellow supergiant that varies regularly every 5 days, 9 hours. At its brightest, Delta Cephei reaches magnitude 3.5, twice as bright as when it's at its faintest, magnitude 4.4. These variations can easily be tracked with the naked eye. They are caused by pulsations in the size of the star, like a slowly beating heart. In the case of Delta Cephei, its diameter changes from forty to forty-five times that of the Sun.

The variability of Delta Cephei was discovered in 1784 by John Goodricke, a 19-year-old amateur astronomer in York, England. Tragically, while continuing his observations of this star, Goodricke caught pneumonia and died at age 21.

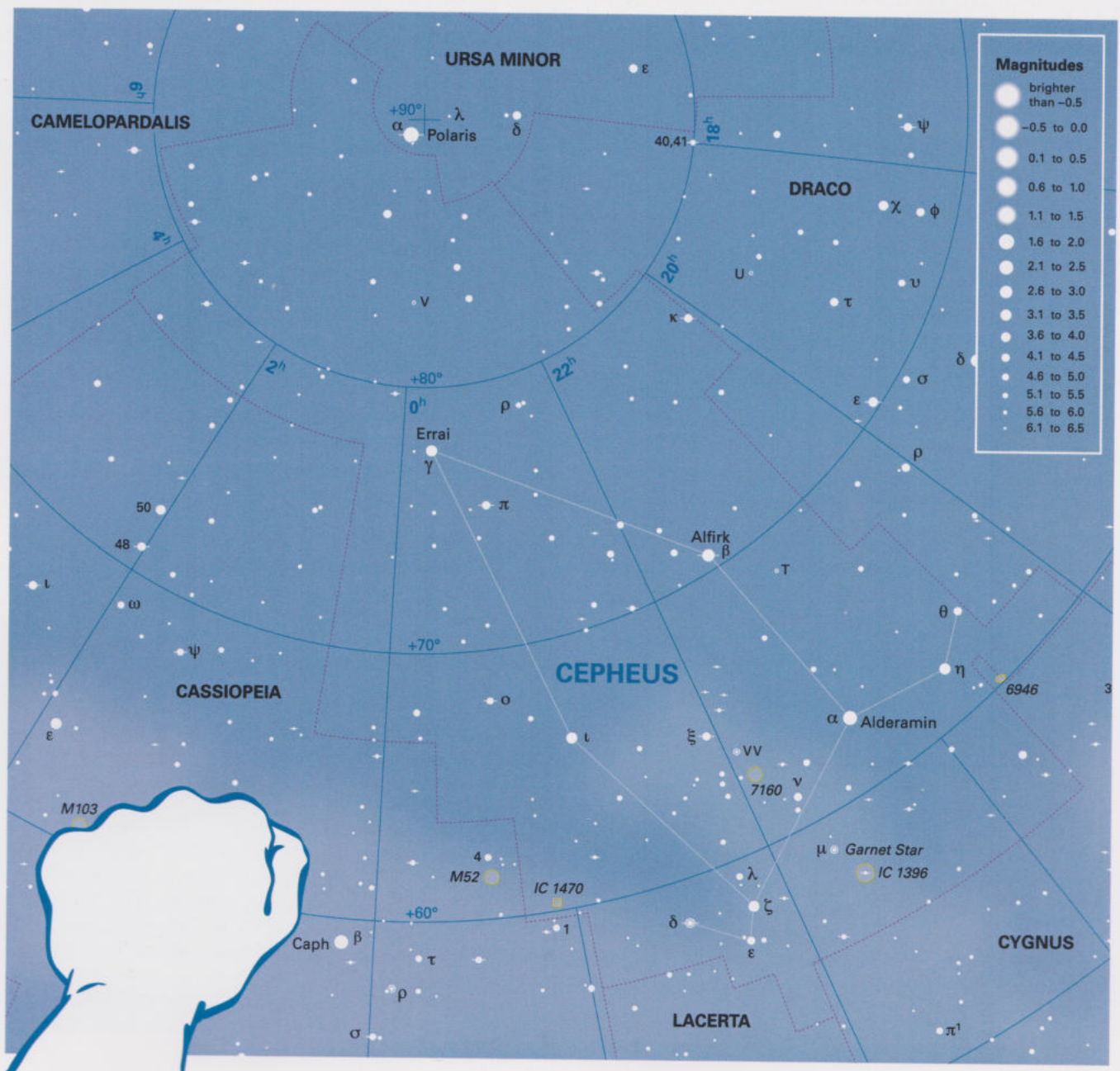
Delta Cephei is the prototype of a class of variable stars known simply as **Cepheids**, which are of particular importance

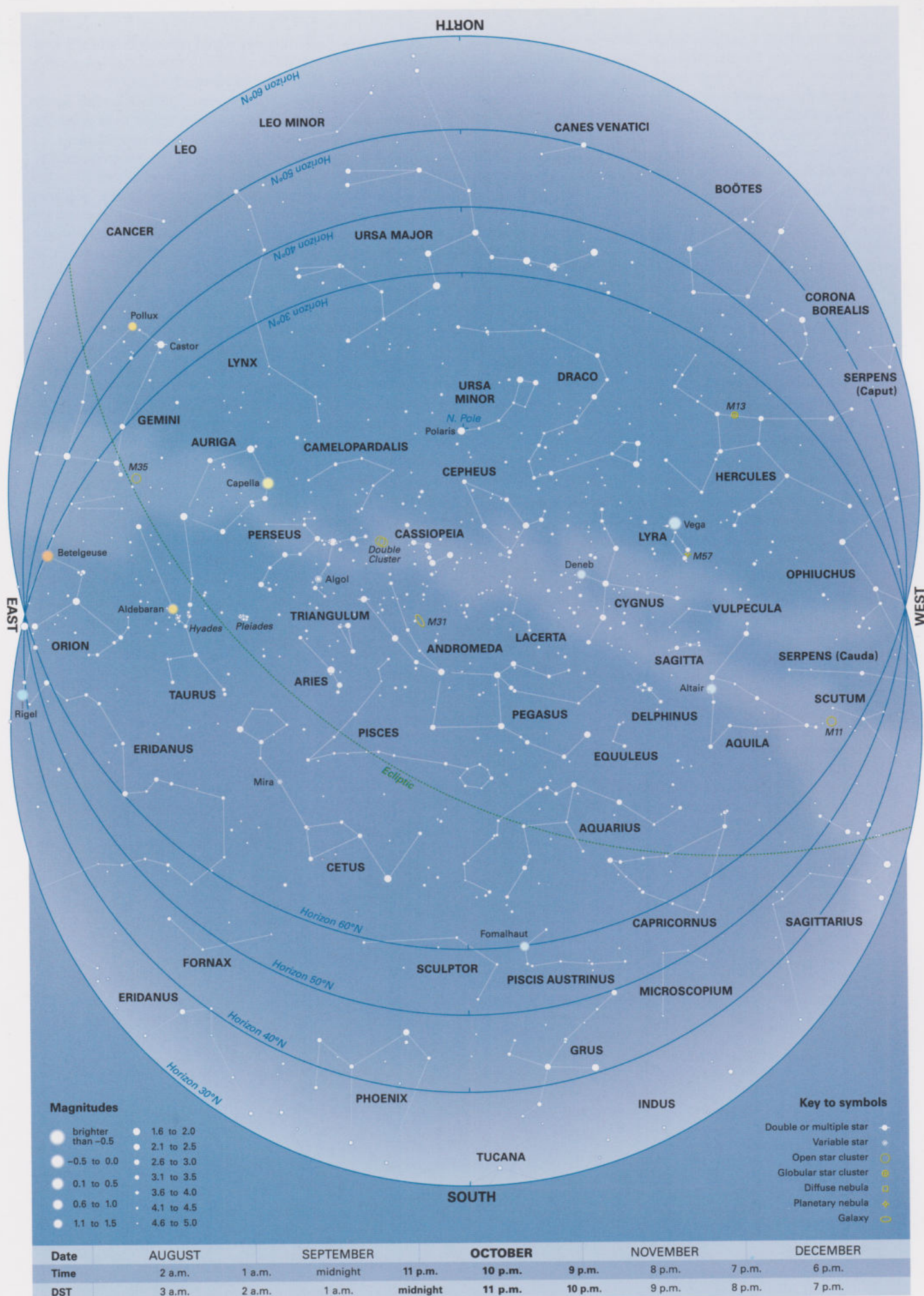
to astronomers. Cepheids are supergiants with surface temperatures of 5,000 to 6,000 K, similar to that of the Sun, so they appear yellowish in color. But being much bigger than the Sun, they are much brighter (5,000 times brighter than the Sun in the case of Delta Cephei) and are easily visible over great distances. Delta Cephei is about 900 light years away from us.

Cepheids vary in brightness by up to two magnitudes (i.e., up to 6.3 times), with periods ranging from about 1 to 135 days. Over 800 Cepheids are known in our Galaxy, and they have been discovered in other galaxies too. The importance of Cepheids is that there is a direct link between their inherent brightness (their luminosity) and their period of variability. The brighter the Cepheid, the longer it takes to vary. Using this relationship, astronomers can deduce the wattage of a Cepheid by monitoring the period of its light changes.

A star's brightness as seen from Earth is affected by its distance from us. Astronomers can work out how far away a Cepheid is by comparing the star's computed wattage with the brightness at which it appears in the sky. Cepheids serve as marker beacons for measuring distances.

Suitable comparison stars for following the light changes of Delta Cephei are Zeta (ζ), Epsilon (ε), and Lambda (λ) Cephei, the same trio used for Mu Cephei. These stars are shown on the chart below.





October

KEY STARS

The Summer Triangle still lingers in the western sky, reluctant to give way to the stars of autumn. Due south, the Square of Pegasus stands high while Fomalhaut twinkles over the southern horizon. Between Pegasus and the north celestial pole, the "W" shape of Cassiopeia is well presented. To the east are Perseus and Auriga, embedded in the Milky Way's starry path. On the eastern horizon, Orion and Gemini are rising. The Big Dipper dips low in the north and is below the horizon for observers at latitude 30°.

The planets this month

Venus

- 2020 Low in the eastern dawn sky throughout the month at mag. -4.0.
- 2021 Reaches greatest elongation (maximum separation from the Sun) of 47° on October 29 at mag. -4.4 in the evening sky, when it appears at half phase through telescopes.
- 2022 Unobservable during the month as it moves behind the Sun. At superior conjunction on October 22.
- 2023 Dominates the eastern dawn sky before sunrise at mag. -4.4. Greatest elongation (maximum separation from the Sun) of 46° is on October 24, when the planet will appear at half phase through telescopes.
- 2024 Low in the western sky after sunset at mag. -4.0.

Mars

- 2020 Prominent all night in southern Pisces. At opposition (south at midnight) on October 13, 62 million km (39 million miles) from Earth, at mag. -2.6, but fades to mag. -2.1 by month's end.
- 2021 At conjunction (behind the Sun) on October 8 and unobservable throughout the month.
- 2022 Visible from late evening until dawn between the horns of Taurus, to the north of Orion, brightening during the month from mag. -0.6 to -1.2.
- 2023 Too close to the Sun for observation as it moves toward conjunction next month.
- 2024 Visible from late evening until dawn in Gemini, brightening from mag. 0.5 to 0.1 during the month.

Jupiter

- 2020 Prominent in the southwestern evening sky in Sagittarius at mag. -2.3. Fainter Saturn, mag. 0.5, lies to its left.
- 2021 A prominent evening object in Capricornus at mag. -2.6.
- 2022 Prominent for most of the night in southern Pisces at a brilliant mag. -2.9.
- 2023 Visible for most of the night in Aries, brightening by month's end to mag. -2.9, as bright as it can ever get, as it approaches opposition next month.
- 2024 Prominent in the late evening and morning sky in Taurus, directly north of Orion, at a brilliant mag. -2.6.

Saturn

- 2020 In the southwestern evening sky at mag. 0.5. Brighter Jupiter remains to its right. Rings tilted Earthward at 23°.
- 2021 An evening object in Capricornus at mag. 0.5. Rings tilted Earthward at 19°.

- 2022 An evening object in Capricornus at mag. 0.6. Rings tilted Earthward at 15°.
- 2023 Visible all evening until after midnight in Aquarius, near the border with Capricornus, at mag. 0.6. Rings tilted Earthward at 10°.
- 2024 Visible all evening until after midnight in Aquarius at mag. 0.7. Rings tilted Earthward at 5° and difficult to see.

Eclipses

Sun

- 2022 October 25. Partial solar eclipse, maximum 86 percent, visible from Europe except the extreme southwest, northeast Africa, the Middle East, and western Asia.
- 2023 October 14. Annular solar eclipse, visible from the western United States, Central America, Colombia, and Brazil; maximum duration 5m, 17s. A partial eclipse is visible across North and Central America and across South America except the far south.
- 2024 October 2. Annular solar eclipse, visible across the southern Pacific Ocean and the far south of South America; maximum duration 7m, 25s. A partial eclipse is visible from the Pacific Ocean, the southern half of South America, and Antarctica.

Moon

- 2023 October 28. Partial lunar eclipse, maximum 12 percent, visible from central and western Australia, Asia, Africa, Europe, and the Atlantic Ocean.

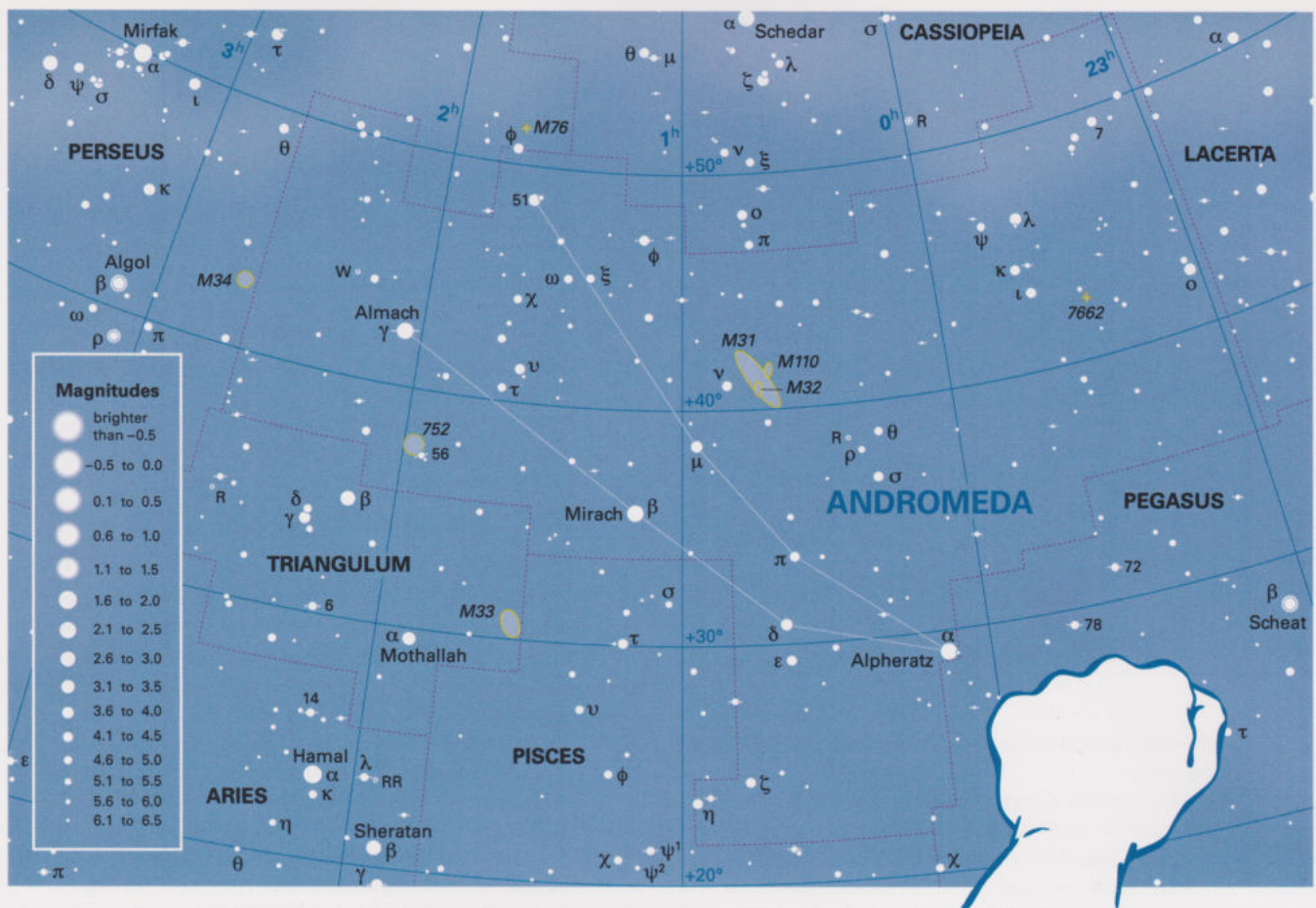
October meteors

One of the year's less spectacular meteor showers, the **Orionids**, radiates from near the Orion-Gemini border every October, reaching a peak of about twenty-five meteors per hour around October 21, although some activity can be seen for up to a week either side of this date. Orionid meteors are fast-moving and can leave dusty trains, but they are not particularly bright, so a dark site will be needed to see them well. Like the Eta Aquariids in May, they are dust released from the famous Halley's Comet. The Orionid radiant does not rise until late, so observations are best made after midnight. The radiant lies due south around 4.30 a.m.

Andromeda

The most famous of all Greek myths, the story of Perseus and Andromeda, is depicted in the skies of autumn. It is the original version of George and the dragon. The tale tells how beautiful Andromeda was chained to a rock by her father, Cepheus, as a sacrifice to appease a terrible monster from the sea that was devastating his country's coastline. The hero, Perseus, happened along just in the nick of time, slayed the monster, and married Andromeda.

Andromeda is not a particularly distinctive constellation. Its most noticeable feature is a curving line of stars that branches off from the top left corner of the Square of Pegasus, forming an immense dipper shape. The star at the top left corner of the Square of Pegasus is Alpha (α) Andromedae. In Greek times, this star was considered common to both Andromeda and Pegasus, but it is now assigned to Andromeda. Its name, Alpheratz, comes from the Arabic, meaning "the horse," reflecting its former association with Pegasus.



Andromeda's body can be traced along the line of 2nd magnitude stars from Alpha, which marks her head, via Beta (β), her waist, to Gamma (γ), her left foot chained to the rock. **Gamma Andromedae** is worth a closer look, for it is an impressive double star with a fine color contrast, like a tighter version of Albireo in Cygnus. The main star of Gamma Andromedae, magnitude 2.2, is an orange giant very similar to Arcturus. Small telescopes show that it has a 5th magnitude blue companion. This companion star is a close double, but large telescopes are needed to separate the two components.

South of Gamma Andromedae is an even easier double, **56 Andromedae**, whose unrelated 6th magnitude components are so wide apart that they are divisible in binoculars. This pair of orange giant suns seemingly lies on the edge of **NGC 752**, a widespread cluster of faint stars, but they are foreground objects, not members of the cluster.

Completing a triangle with Gamma and 56 Andromedae is **Upsilon (υ) Andromedae**, a 4th magnitude star similar to the Sun. It's worth locating because it is the first star around which a multiplanet system was discovered. Four planets are known, with masses ranging from that of Saturn to about fourteen times that of Jupiter. Other planets of Earth-like mass might exist but are undetected. Upsilon Andromedae is 44 light years away.

Andromeda contains one of the easiest planetary nebulae for small telescopes, **NGC 7662**. Look for it one Moon's breadth from the 6th magnitude star 13 Andromedae. At first glance it resembles a fuzzy star of 9th magnitude. But higher powers show its slightly elliptical outline, similar in size to the disk of Mars, with the luminous blue-green tinge typical of planetary nebulae. Anyone who thinks that planetary nebulae require large apertures should try NGC 7662.

Overshadowing all else in Andromeda is the great spiral galaxy **M31**, a near-twin of the Milky Way. A line from Beta (β) through Mu (μ) Andromedae points to it. Under averagely clear skies, M31 appears to the naked eye as a faint elliptical glow, high overhead. M31 is the farthest object visible to the naked eye, 2.5 million light years away. As you gaze upward at M31, consider that the light entering your eyes has been traveling for 2.5 million years, since the time when our ape-like ancestors roamed the plains of Africa.

M31 has a special place in the history of astronomy. It was the first object identified as a separate galaxy outside our own Milky Way. In 1924, the American astronomer Edwin Hubble used the 2.5 meter (100 inch) Mount Wilson reflector, then the largest telescope in the world, to take long-exposure photographs of M31. The photographs showed that it contained individual stars, but they're so faint that they must lie far beyond the stars of our Milky Way. Until then, M31 and objects like it had been assumed to be spiral-shaped clouds of gas within the Milky Way. Now we know that the Milky Way is but one galaxy in a Universe full of countless other galaxies, stretching as far as the largest telescopes can see.

It is easy to understand why previous astronomers failed to recognize the true nature of M31. Even in large telescopes, it appears as a nebulous patch with no hint of individual stars. Binoculars show it unmistakably, extending up to several Moon diameters, half the width of your outstretched fist. It appears elliptical because we are seeing it at an angle. See how far you can trace its faint outer regions; its extent depends on sky conditions and the instrument used. Small telescopes tend to show only the brightest inner regions of the galaxy.

M31 has two small companion galaxies visible in small telescopes. One Moon diameter south of M31 lies **M32**, which looks like a fuzzy 8th magnitude star. The other, **M110**, lies twice as far to the north and is more difficult to spot; it is larger and more diffuse.

Seen from outside, our own Galaxy would look much like M31. Of the two, M31 seems to be the larger, with a diameter of about 150,000 light years and containing 400 billion stars, twice the number in the Milky Way. Do any of those stars have planets where inquisitive life forms are looking back at us?

Our Galaxy and M31 are the two largest members of a cluster of over fifty galaxies of various sizes called the Local Group. To find another member of the Local Group, look over the border from Andromeda into Triangulum. There lies **M33**, another spiral galaxy, somewhat farther away than M31. It is presented face-on to us and covers a larger area of sky than the full Moon, but it is notoriously difficult to detect because its light is so pale. Dark skies are essential to see M33, and binoculars are better than telescopes because they condense its thinly spread light. Sometimes observers overlook M33 because it is much larger than they expect.

Pegasus

Pegasus represents the winged horse that was born from the blood of Medusa when she was beheaded by Perseus. Only the front quarters of the horse are depicted in the sky. Pegasus is sometimes identified as the horse of Perseus, but it was another hero, Bellerophon, who rode Pegasus. The constellation is the seventh-largest in the sky but contains no outstandingly bright stars. Its most distinctive feature is the **Great Square of Pegasus**, whose corners are marked by four stars of 2nd and 3rd magnitudes, although only three of the stars belong to Pegasus. The fourth star is Alpha Andromedae, which on some old maps was called Delta Pegasi.

Pegasus is upside-down in the sky. The Great Square represents his body, and the crooked line of stars leading from the bottom right of the Square to Epsilon (ε) Pegasi marks his neck and head. The two lines of stars from the upper right of the Square are his forelegs.

The Square of Pegasus is a large feature, with a diameter of over 15°, which is about the width of two outstretched fists, enough to contain a line of more than thirty Moons side by side. Yet within this large area of sky, only a handful of stars are visible to the naked eye. How many stars can you count here?

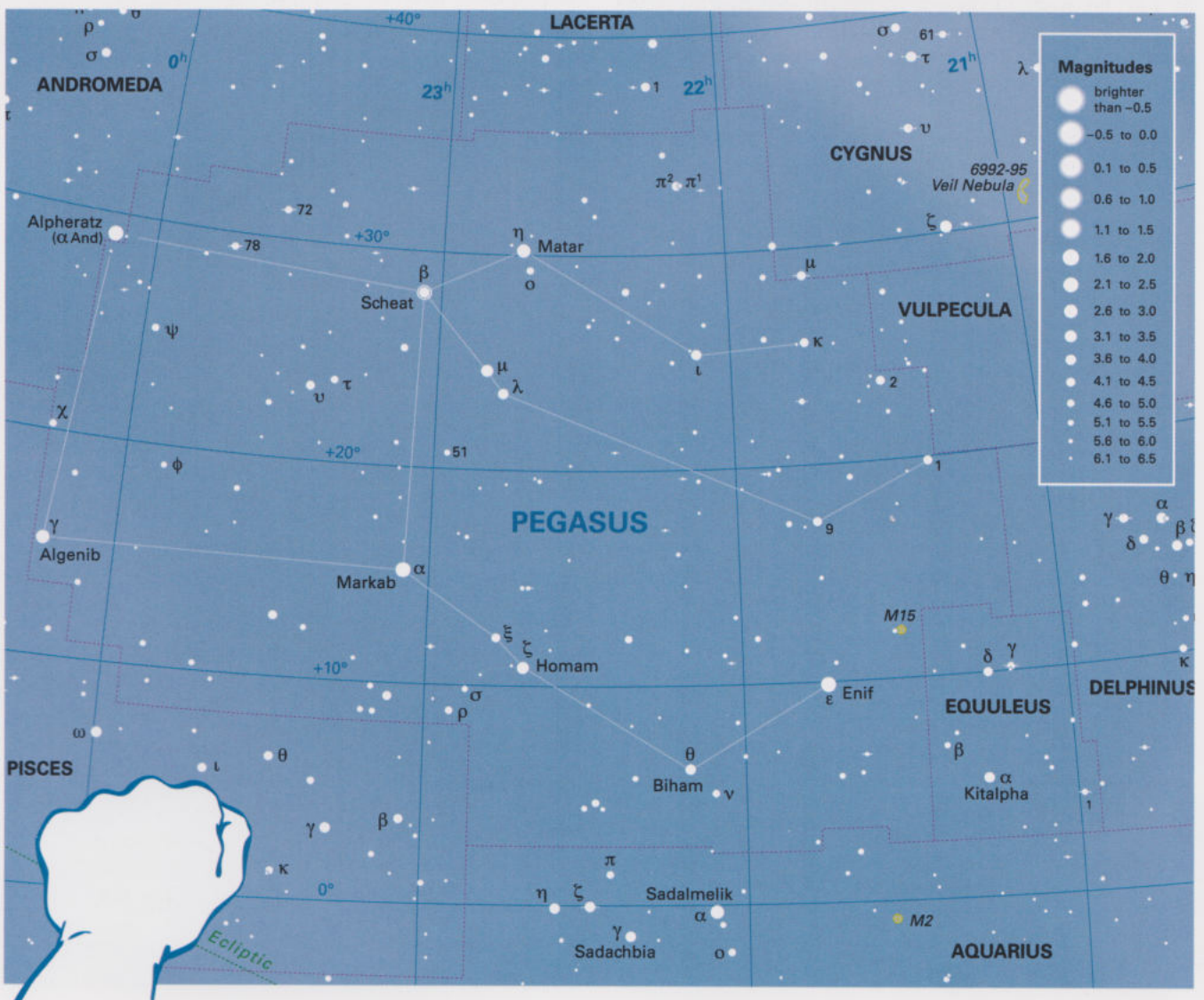
The star at the top right of the Square is **Beta (β) Pegasi**, also known as Scheat, an immense red giant approximately 100 times the diameter of the Sun. It varies irregularly in size and brightness between magnitudes 2.3 and 2.7. Compare it with the other stars of the Square, Alpha (α) Pegasi, or Markab, magnitude 2.5, and Gamma (γ) Pegasi, Algenib, magnitude 2.8.

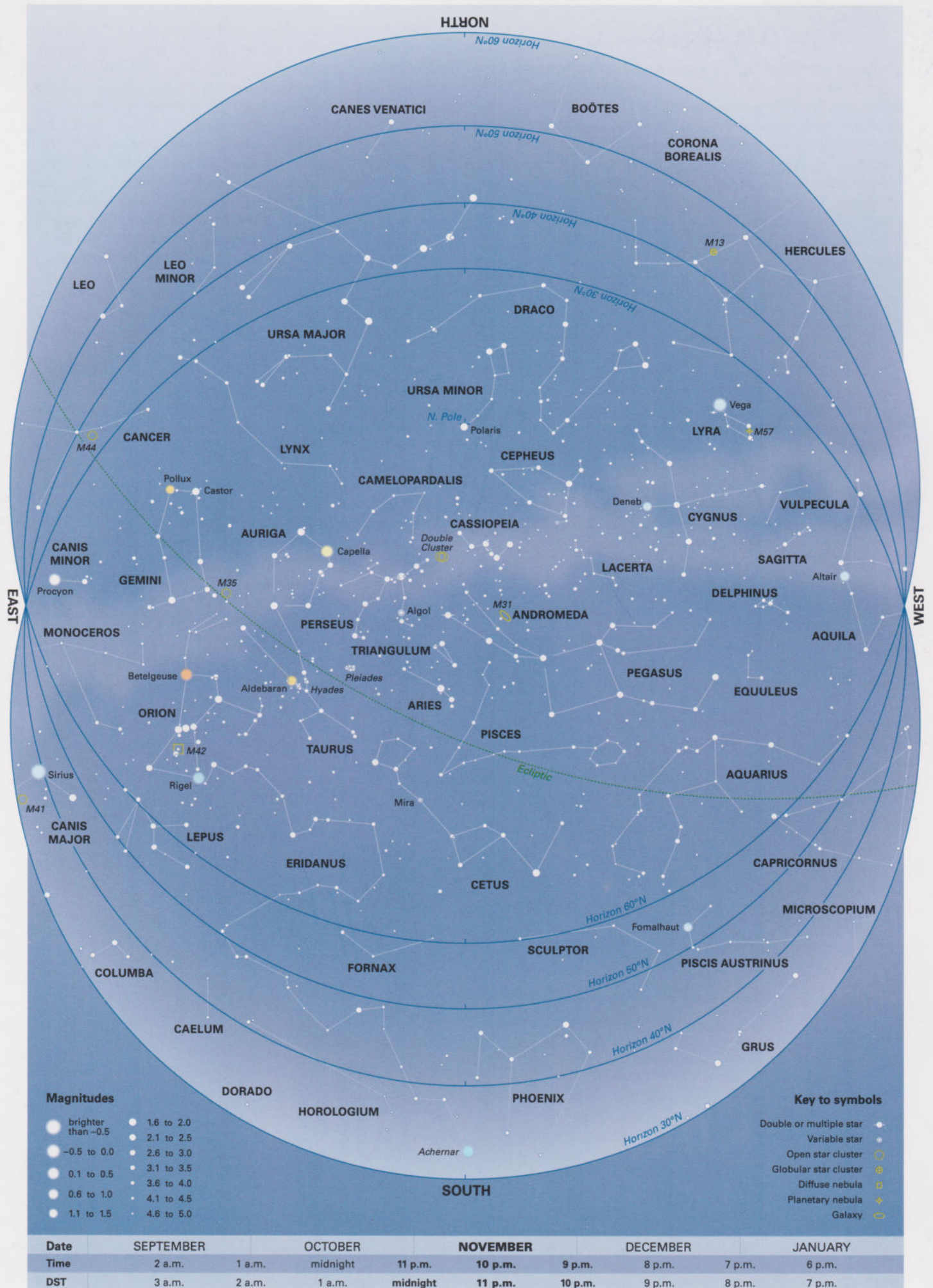
About halfway down the right-hand side of the Square lies an unassuming 5th magnitude star. This is **51 Pegasi**, which achieved lasting fame in 1995 when it became the first star beyond the Sun discovered to have a planet orbiting it. The star itself, which lies 50 light years away, is similar to the Sun. The planet has a mass about half that of Jupiter but swings around 51 Pegasi in only four days, a remarkably short "year," which means that it must be much closer to the star than any of the planets in our own Solar System are to the Sun. Many other examples of stars with planets have since been confirmed, including the first multiple-planet system around Upsilon (υ) Andromedae (see page 62).

The brightest star in the constellation is **Epsilon (ε) Pegasi**, otherwise known as Enif, from the Arabic, meaning "nose." It is a brilliant orange supergiant nearly 700 light years away, appearing of magnitude 2.4. Binoculars or small telescopes show it to have a wide companion star of 8th magnitude.

Above and to the right of Epsilon Pegasi is the greatest treasure of this constellation, the globular cluster **M15**. It is just too faint to be seen with the naked eye under normal conditions, but it shows up clearly in binoculars as a rounded, fuzzy patch of light. A 6th magnitude star lies nearby, acting as a guide to its location.

Small telescopes show that the cluster has a bright core, where its stars crowd together most densely, although small apertures will be unable to resolve individual stars. The rest of the cluster is like a misty halo around this bright center. M15 lies 34,000 light years away from us.





November

KEY STARS

The Milky Way arches overhead, passing through Cassiopeia and Perseus. The Summer Triangle reluctantly departs in the west, but the Square of Pegasus is still high in the southwest. Due south is the barren area of Pisces, Cetus, and Eridanus, with no prominent stars, although the 1st magnitude star Achernar peeps above the southern horizon as seen from 30° north. Aldebaran, the red eye of Taurus the Bull, and yellow Capella stand prominently in the southeast, followed by Gemini and Orion, signaling the approach of winter.

The planets this month

Venus

- 2020 Low in the eastern dawn sky at mag. -4.0, and difficult to see in twilight from more northerly latitudes.
- 2021 Low in the southwestern evening sky at mag. -4.5, but difficult to see from mid- and far-northern latitudes.
- 2022 Too close to the Sun for observation all month.
- 2023 Prominent in the southeastern morning sky at mag. -4.2.
- 2024 Low in the southwestern evening sky at mag. -4.1 as seen from more southerly latitudes, but too low for observation from mid-northern latitudes and above.

Mars

- 2020 Visible for most of the night in Pisces, fading rapidly during the month from mag. -2.1 to mag. -1.1.
- 2021 Too close to the Sun for observation all month.
- 2022 Visible for most of the night in Taurus, above Orion, brightening from -1.2 to -1.8 as it approaches opposition.
- 2023 Unobservable as it moves behind the Sun. At conjunction (behind the Sun) on November 18.
- 2024 Visible from late evening until dawn in Cancer, brightening rapidly from mag. +0.1 to -0.5 during the month.

Jupiter

- 2020 In the southwestern evening sky at mag. -2.1, becoming low as seen from more northerly latitudes. Fainter Saturn, mag. 0.6, lies to its upper left.
- 2021 In the evening sky in Capricornus, near the border with Aquarius, at mag. -2.4.
- 2022 Prominent all evening and into the early hours in southern Pisces at a brilliant mag. -2.7.
- 2023 Prominent all night in Aries. At opposition (south at midnight) on November 3, 596 million km (370 million miles) from Earth at mag. -2.9, as bright as it can ever appear.
- 2024 Prominent all night in Taurus at a brilliant mag. -2.8.

Saturn

- 2020 In the southwestern evening sky at mag. 0.6, becoming low as seen from more northerly latitudes. Moves closer to brighter Jupiter during the month. Rings tilted Earthward at 22°.
- 2021 In the southwestern evening sky in Capricornus at mag. 0.7. Rings tilted Earthward at 19°.
- 2022 In the southwestern evening sky in Capricornus at mag. 0.7. Rings tilted Earthward at 15°.
- 2023 An evening object in Aquarius, near the border with Capricornus, at mag. 0.8. Rings tilted Earthward at 10°.

- 2024 An evening object in Aquarius at mag. 0.9. Rings tilted Earthward at 5° and difficult to see.

Eclipses

Moon

- 2021 November 19. Partial lunar eclipse, maximum 98 percent, visible from northwestern Europe, the northern Atlantic, the Americas, the Pacific Ocean, Australasia, and east Asia.
- 2022 November 8. Total lunar eclipse, visible from the Americas, the Pacific Ocean, Australasia, and eastern and central Asia. Totality starts at 10:16 GMT, ends 11:42 GMT.

November meteors

Two meteor showers can be seen in November: the Taurids and the Leonids. The **Taurids** have an extended period of activity that lasts for most of October and November from two radiants, one 12° north of the other. The southern stream peaks around October 10 and the northern one around November 12; at maximum up to ten meteors per hour can be seen coming from the region near the Pleiades and Hyades star clusters. Taurid meteors are debris from Comet Encke, the comet with the shortest-known orbital period, 3.3 years. Taurids are slow-moving and bright, which makes the display more impressive than their low numbers might suggest.

Altogether more spasmodic is the **Leonid** shower, which radiates from near Gamma (γ) Leonis, peaking around November 17–18. Leonids are swift, stabbing meteors, often flaring at the end of their paths. Many leave persistent trains. Since Leo does not rise until late, observations have to be made after midnight. The Leonids are associated with Comet Tempel–Tuttle, which orbits the Sun every thirty-three years. As with the Taurids, rates are usually modest, no more than ten per hour. But spectacular Leonid storms can occur at thirty-three-year intervals, when Comet Tempel–Tuttle returns to the inner region of the Solar System and the Earth encounters a dense swarm of cometary dust. In 1966, observers in the United States saw Leonid meteors falling from the sky like rain, reaching a peak of thousands per minute. Rates of a few thousand per hour were seen in 1999, 2001, and 2002 following the last return of the Leonids' parent comet.

Perseus

Perseus, a son of Zeus, is the hero in the most enduring of Greek myths. His adventures began when he was sent to kill Medusa, one of the three Gorgons, winged monsters with snakes for hair who were so terrible to behold that anyone who looked at them turned to stone. Perseus sneaked up on Medusa while she was sleeping, looking only at her reflection in his shield to avoid petrification. He decapitated Medusa with one swing of his sword and flew off with her head in a bag. While flying home, he saw the beautiful maiden Andromeda chained to a rock as a sacrifice to a sea monster. Perseus swooped down, killed the monster, and claimed Andromeda as his bride.

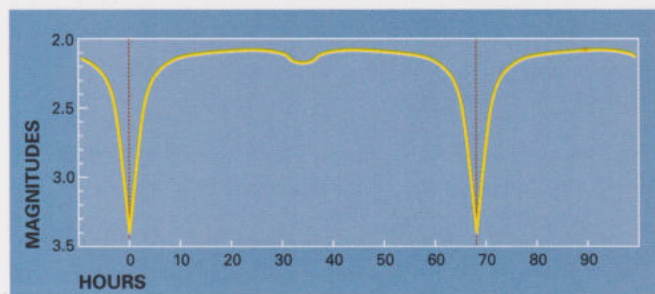
In the sky, Perseus is depicted holding aloft the head of Medusa, marked by **Beta (β) Persei**, known by its Arabic name, **Algol**, meaning "ghoul" or "demon." The name is appropriate, since Algol is a variable star that appears to "wink" like an evil eye at regular intervals, from magnitude 2.1 to 3.4. Algol's variations in light were first recognized by the Italian



astronomer Geminiano Montanari in 1667. The periodicity of the variations was first measured by the English amateur astronomer John Goodricke in 1783. Goodricke correctly suggested that the variations were caused by eclipses.

Algol is an eclipsing binary, consisting of two stars that regularly pass in front of each other as seen from Earth. The stars are too close together to be distinguished in a telescope, but analysis of the light from Algol reveals that the brighter of the pair, Algol A, is a hot star 100 times as luminous as the Sun. Its companion, Algol B, is a larger but fainter orange star that covers about 80 percent of Algol A during the eclipses. There is also a third star in the system, Algol C, but it does not participate in the eclipses.

Algol's eclipses occur every 2 days, 20 hours, 49 minutes. In a mere five hours, Algol fades to one-third of its usual brightness, from magnitude 2.1 to 3.4, then returns to magnitude 2.1 in another five hours. These variations are easily followed with the naked eye. Compare Algol with Beta (β) Cassiopeiae, magnitude 2.3; Delta (δ) Cassiopeiae, mag. 2.7; Epsilon (ϵ) Persei, mag. 2.9; Delta (δ) Persei, mag. 3.0; Alpha (α) Trianguli, mag. 3.4; and Kappa (κ) Persei, mag. 3.8. You should end up with a light curve



The winking demon: Graph of brightness changes of the variable star Algol, in Perseus. Every 2.87 days, the fainter of an orbiting pair of stars eclipses its partner and their combined brightness dips from magnitude 2.1 to 3.4. The dimming is easily noticeable to the naked eye.

looking like the one shown below. A secondary minimum occurs when Algol A eclipses Algol B, but the fading is so slight that it is undetectable to the eye. Do not compare Algol with **Rho** (ρ) **Persei**, which is a red giant that fluctuates somewhat irregularly between magnitudes 3.3 and 4.0 every month or two.

Perseus lies in a sparkling part of the Milky Way. Look at the region around the constellation's brightest star, **Alpha** (α) **Persei**, magnitude 1.8. Alpha Persei is a yellow-white supergiant that is 5,000 times more luminous than the Sun and surrounded by a sprinkling of bright stars that form a loose cluster about 550 light years away. Note also the cluster **M34** on the border with Andromeda, an excellent object for binoculars and small telescopes. M34 consists of several dozen stars of 8th magnitude and fainter and covers a similar area of sky to the full Moon. M34 lies 1,600 light years away.

The real showpiece of Perseus is the **Double Cluster**, a twin star cluster on the border with Cassiopeia, marking the hand of Perseus holding aloft his sword. To the naked eye, the clusters resemble a denser knot in the Milky Way. Binoculars and small telescopes show this area to be full of stars, one of the finest sights in the sky for small instruments. Note an arc of stars that leads northward to a large, scattered cluster on the border with Cassiopeia, known as **Stock 2**.

Each half of the Double Cluster covers a greater area of sky than the full Moon. However, the two clusters are not identical twins. **NGC 869**, also known as **h Persei**, is the more star-packed of the two. The other cluster, **NGC 884**, also known as **Chi** (χ) **Persei**, contains some red giant stars, which NGC 869 does not. NGC 884 is older, so its stars have had more time to evolve. Both clusters lie about 8,000 light years away from us in a spiral arm of our Galaxy. To be visible over such distances, the brightest stars in each cluster must be intensely luminous supergiants, similar to Rigel and Betelgeuse in Orion. If the Double Cluster were as close to us as the stars of Orion, it would appear as spectacularly large and bright to the naked eye as we see it through binoculars.

Auriga

Next to Perseus in the sky is the hexagonal shape of Auriga, representing a man driving a chariot. Compared to the flamboyant figure of Perseus, the identity of Auriga is somewhat shadowy. He is usually said to be Erichthonius, a lame king of Athens who invented the four-horse chariot. Another legend identifies Auriga with Myrtilus, charioteer of King Oenomaus and a son of Hermes.

There is no mistaking the constellation's brightest star, Alpha (α) Aurigae, better known as **Capella**. At magnitude 0.1, Capella is the sixth-brightest star in the sky. Its name comes from the Latin, meaning "little she-goat," for the charioteer has traditionally been depicted carrying a goat on his left shoulder. Capella is a pair of yellow giants forming a spectroscopic binary, 43 light years away. It is the most northerly of all 1st magnitude stars.

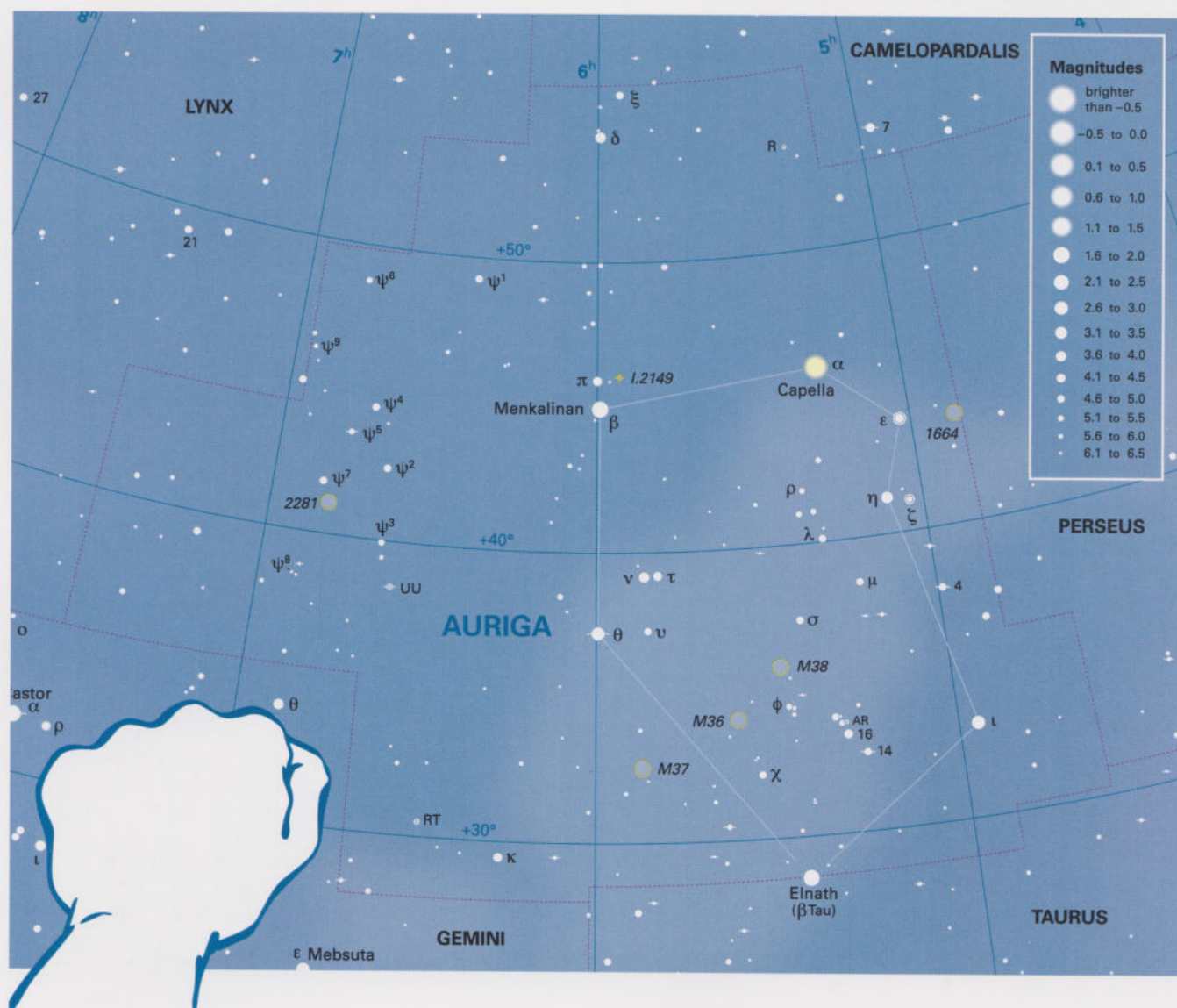
The stars Eta (η) Aurigae and Zeta (ζ) Aurigae are known as the Kids, the goat's offspring; they are carried on the charioteer's arm. **Zeta Aurigae** is one of two extraordinary eclipsing binary stars in this constellation. It consists of an orange giant 150 times larger than the Sun, orbited by a blue-white star similar to Regulus. Although this blue-white star is smaller than the much brighter giant, it is about four times the diameter of the Sun. The luminosities of the two stars are 700 and 140 Suns, respectively. Normally Zeta Aurigae shines at magnitude 3.7, but every 2 years, 8 months, the smaller star is eclipsed by the red giant and the brightness falls by a third, to magnitude 4.0. The eclipses last six weeks, after which the star returns to its normal brightness.

Even more extraordinary is **Epsilon (ε) Aurigae**, which has the longest known period of any eclipsing binary, twenty-seven years. The main star is an intensely luminous white supergiant, one of the most powerful stars known, shining with the light of over 100,000 Suns and large enough to contain the orbit of the Earth. It lies about 2,000 light years away. Normally it appears at magnitude 3.0, but every twenty-seven years it is partially eclipsed by a mysterious dark companion. Over a period of four months, the star's brightness gradually halves, to magnitude 3.8, where it remains for fourteen months before returning to normal.

The nature of Epsilon Aurigae's dark companion was a mystery to astronomers for years. It is now thought to consist of a close pair of stars surrounded by a dark disk of dust that causes the eclipses. Epsilon Aurigae was last eclipsed in 2009 to 2011, and the next eclipse will begin in late 2036.

Auriga is notable for an impressive trio of open star clusters, **M36**, **M37**, and **M38**, all three being visible in the same field of view through wide-angle binoculars. In binoculars they appear as fuzzy patches, but small telescopes resolve them into individual stars. Each cluster has its own distinct character.

M36 is the smallest and most condensed of the trio, consisting of sixty or so stars of 9th magnitude and fainter, lying 4,300 light years away. In binoculars, it appears as the most prominent of the Auriga clusters. The largest and richest of the Auriga clusters is M37, containing 150 or so stars 4,500 light years away. At its center is a brighter orange star. The most scattered of the clusters is M38, containing about 100 faint stars, 4,600 light years away.





December

KEY STARS

The misty-looking Pleiades cluster is due south at 10 p.m. in mid-month. Above it is Perseus, flanked by the "W" shape of Cassiopeia and boxy Auriga. Following the Pleiades across the sky is the "V"-shaped Hyades group, with ruddy Aldebaran at one tip. Orion marches grandly upward from the southeast, followed by his dogs, brilliant Procyon and Sirius. Between Orion and the pole glitters Capella. High in the east are Castor and Pollux, the twin stars of Gemini. Below them, on the eastern horizon, the head of Leo is rising. In the southwest is the Square of Pegasus, making a diamond shape as it stands on one corner. Vega lingers on the northwestern horizon, for observers above latitude 45° north.

The planets this month

Venus

- 2020 Becomes engulfed in dawn twilight during the month as its separation from the Sun decreases.
- 2021 Reaches mag. -4.7, as bright as it can ever get, in the first half of December, when it appears as a crescent through small telescopes, but then becomes lost in twilight in the southwestern evening sky.
- 2022 Too close to the Sun for observation all month.
- 2023 Prominent in the southeastern dawn sky at mag. -4.1, but becoming low by the end of the month for more northerly observers.
- 2024 Prominent in the southwestern evening sky at mag. -4.2, becoming easier to see during the month as it moves toward greatest elongation early next year.

Mars

- 2020 An evening object in Pisces, fading from mag. -1.1 to -0.2. Ends the month near the border with Aries.
- 2021 Emerges into the southeastern dawn sky at mag. 1.6 by month's end as seen from mid-northern latitudes and below, but still lost in twilight from farther north.
- 2022 Visible all night in Taurus. At opposition (south at midnight) on December 8, 82 million km (51 million miles) from Earth, at mag. -1.9, lying next to the full Moon. Ends the month north of the Hyades cluster at mag. -1.2.
- 2023 In the southeastern dawn twilight at month's end for the most southerly observers at mag. 1.3, but too low to see from mid-northern latitudes and above.
- 2024 Visible for most of the night, almost stationary in Cancer. Brightens rapidly from mag. -0.5 to -1.2 as it approaches opposition next January.

Jupiter

- 2020 Low in the southwestern evening sky after sunset at mag. -2.0, becoming increasingly difficult to see during the month as it moves closer to the Sun.
- 2021 In the southwestern evening sky at mag. -2.2, moving from Capricornus into Aquarius in mid-month.
- 2022 An evening object in southern Pisces at mag. -2.5.
- 2023 Prominent for most of the night in Aries at mag. -2.7.
- 2024 Prominent all night in Taurus. At opposition (south at midnight) on December 7, 612 million km (380 million miles) from Earth at mag. -2.8, almost as bright as it can ever become. Ends the year just north of the Hyades.

Saturn

- 2020 Low in the southwestern evening sky after sunset at mag. 0.6, becoming increasingly difficult to see during the month as it moves closer to the Sun. Passes brighter Jupiter (mag. -2.0) in the evening twilight in the second half of the month. Rings tilted Earthward at 21°.
- 2021 In the southwestern evening sky after sunset at mag. 0.7, becoming low by month's end as seen from more northerly latitudes. Rings tilted Earthward at 18°.
- 2022 In the southwestern evening sky after sunset at mag. 0.8. Rings tilted Earthward at 14°.
- 2023 In the southwestern evening sky at mag. 0.9. Rings tilted Earthward at 10°.
- 2024 In the western evening sky in Aquarius at mag. 1.0. Rings tilted Earthward at 5° and difficult to see.

Eclipses

Sun

- 2020 December 14. Total solar eclipse, visible from the southern Pacific Ocean, southern Chile and Argentina, and the southern Atlantic Ocean; maximum duration 2m, 10s. A partial eclipse is visible across the southern Pacific Ocean, southern South America, the southern Atlantic Ocean, and Antarctica.
- 2021 December 4. Total solar eclipse, visible from Antarctica; maximum duration 1m, 24s. A partial eclipse is visible from Antarctica, South Africa, and the southern Indian Ocean.

December meteors

The **Geminids** are one of the brightest and richest showers of the year. At their peak, around December 13–14, as many as 100 meteors per hour may be seen radiating from near Castor. The radiant is well placed for observation throughout the night. Geminid meteors are bright, like the Perseids, but unlike the Perseids they rarely leave trains. Activity falls off sharply after the maximum. The Geminids are unique in that their parent body is not a comet but an asteroid. This asteroid, which has an orbital period of 1.4 years, was discovered in 1983 and was named Phaethon. It is probably the "dead" nucleus of a former comet.

Taurus

As the year draws to a close, the familiar figure of Taurus, the Bull, snorts the night air in the south. His face is marked by the "V"-shaped cluster of stars called the Hyades, his glinting red eye is the bright star Aldebaran, and his long horns are tipped by the stars Zeta (ζ) and Beta (β) Tauri. Long ago, Beta Tauri was regarded as being common to both Auriga and Taurus, and on old star maps, it was given the alternative designation of Gamma (γ) Aurigae, but now it is the exclusive property of Taurus. Its Arabic name, Elnath, means "the butting one."

Only the top half of the Bull is depicted in the sky. This might be explained by one legend, which identifies Taurus as the bull that Zeus changed into to seduce Princess Europa of Tyre. He carried her on his back through the ocean, so perhaps the rest of the Bull is immersed beneath the waves. Another identification of Taurus is as the Cretan bull tamed by Hercules as one of his twelve labors.

The brightest star in the constellation, Alpha (α) Tauri, better known as **Aldebaran**, has a noticeably fiery glow, like a red-hot coal. It is an orange giant star, twenty-five times the diameter of the Sun and 150 times as bright. The name Aldebaran comes from the Arabic, meaning "the follower," because it follows the Hyades and Pleiades star clusters across the sky. Aldebaran lies 67 light years away and appears of magnitude 0.9. Aldebaran looks as though it is a member of the **Hyades** star cluster, but it is not. It is a foreground object at less than half the distance, superimposed on the Hyades by chance.

In mythology, the Hyades and Pleiades were sisters, the daughters of Atlas, but with different mothers. Aethra was the mother of the Hyades, while Pleione was the mother of the Pleiades.

According to legend, there were five Hyades, but at least a dozen stars are visible to the naked eye. The Hyades cluster spans 5° of sky; it's so large that only binoculars can capture all of it. As you look at the numerous stars, note several bright, wide doubles, including **Theta (θ) Tauri** and **Sigma (σ) Tauri**. At magnitude 3.4, Theta-2 (θ^2) Tauri is the brightest star in the cluster, followed closely by Epsilon (ϵ) Tauri, magnitude 3.5, and Gamma (γ) Tauri, magnitude 3.6.

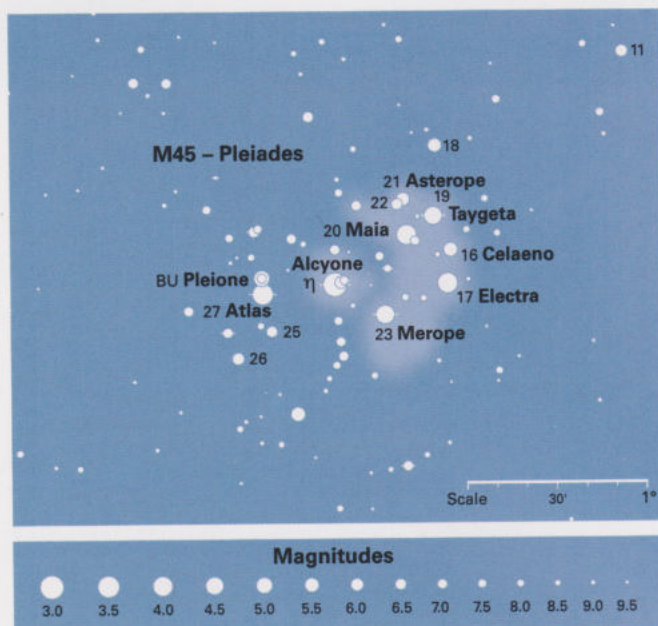
Hundreds of stars belong to the Hyades, all of them moving through space together toward a point in the sky near Betelgeuse. The cluster's distance can be accurately derived from the movements of its stars. Measured in this way, the Hyades turns out to be 150 light years away, making it the nearest star cluster to us. The distance of the Hyades is the first stepping stone in our scale of the Universe.

Even the Hyades is overshadowed by its near neighbor the **Pleiades**, commonly known as the Seven Sisters, the most famous of all star clusters. The Pleiades hover like a swarm of flies over the Bull's back. At first glance, the Pleiades appear as a misty patch. Good eyesight reveals six or seven individual stars, and some people with exceptional eyesight can see ten or more. The misty effect is produced by the dozens of fainter stars that are just beyond visibility with the naked eye. Without a doubt, the Pleiades cluster is the finest binocular sight in astronomy.

Unlike the Hyades cluster, none of whose stars are named, the stars of the Pleiades bear the names of all seven sisters: Alcyone, Asterope, Celaeno, Electra, Maia, Merope, and Taygeta. Their father and mother, Atlas and Pleione, are also present. There is even a legend to explain why only six Pleiades, rather than seven, are easily visible. Electra is said to have hidden her face so as not to witness the ruins of Troy, the city founded by her son Dardanus. But some say that the "missing" Pleiad is Merope, ashamed because she was the only one of the sisters to wed a mortal. The naming of the Pleiades has not followed either legend because the faintest of the named stars in the cluster are Asterope and Celaeno.

In addition to the named stars, binoculars bring into view a glittering array of dozens more, fitting snugly into the field of view. At least 100 stars are members of the cluster, lying 440 light years away, nearly three times as far as the Hyades. The main stars of the Pleiades form a shape resembling a squashed version of the Big Dipper. The full Moon could fit into the bowl of the Pleiades "dipper" without obscuring either Alcyone or Taygeta. The whole cluster extends across more than two Moon widths.

The brightest member of the Pleiades is **Alcyone**, also known as Eta (η) Tauri, magnitude 2.9, a blue-white giant 800 times more luminous than the Sun. **Pleione**, also known as **BU Tauri**, is an interesting variable of the type known as a shell star. It rotates so quickly, about 100 times faster than our Sun, that it is unstable and throws off shells of gas, causing it to vary gradually in brightness; currently it is around 5th



PLEIADES

Star	Magnitude
Alcyone (η Tauri)	2.9
Atlas (27 Tauri)	3.6
Electra (17 Tauri)	3.7
Maia (20 Tauri)	3.9
Merope (23 Tauri)	4.2
Taygeta (19 Tauri)	4.3
Pleione (BU Tauri)	4.8–5.5 (variable)
Celaeno (16 Tauri)	5.5
18 Tauri	5.6
Asterope (21 Tauri)	5.8
22 Tauri	6.4

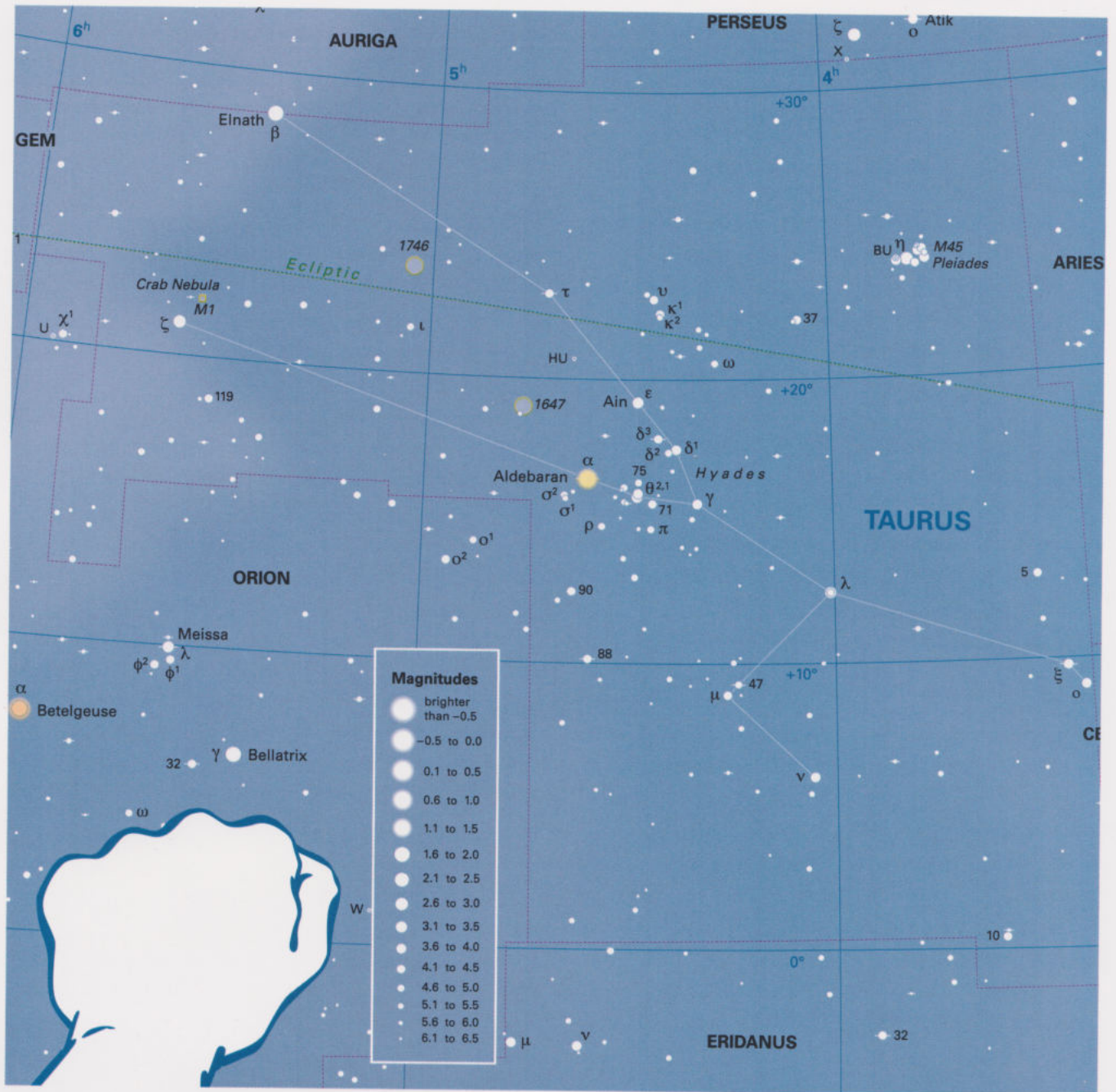
magnitude. Perhaps Pleione was much brighter in the past and is really the "missing" Pleiad.

The Pleiades cluster is relatively young, with an estimated age of 50 million years, compared to 600 million years for the Hyades. But the brightest members of the Pleiades, which stud the binocular field like priceless blue-white diamonds, are no more than a few million years old. Long-exposure photographs show that the Pleiades stars are surrounded by traces of gas and dust, but this nebulosity is not visible through amateur instruments except under the most exceptional conditions. The nebulosity was once thought to be the remnants of the cloud from which the stars formed. More recent research suggests it is an unrelated cloud into which the cluster has since drifted by chance.

The star **Lambda (λ) Tauri** in the bull's chest is an eclipsing binary of the same type as Algol in Perseus. Lambda Tauri is normally of magnitude 3.4, but every four days it sinks to magnitude 3.9 as it is partially eclipsed by a fainter companion. The decline and rise take about a day each.

Taurus is blessed with exceptional objects. In addition to the Hyades and Pleiades clusters, it contains the **Crab Nebula**, perhaps the most-studied object outside the Solar System. Astronomers also know it as **M1**, the first in the list of nebulous objects compiled by the Frenchman Charles Messier.

The Crab Nebula is the remains of a star much more massive than the Sun that ended its life as a supernova, a cataclysmic nuclear explosion. Astronomers in China saw the star flare up in July 1054 CE. At its brightest, it reached



magnitude -4 , similar to Venus, and was visible in daylight for three weeks. It finally faded from naked-eye view after 21 months, in April 1056. There are no European records of the explosion, probably because astronomy was almost non-existent in Europe at the time.

During its explosion, the Crab supernova must have blazed with the brilliance of 500 million Suns. Twenty-five such supernovae could equal the entire light output of our Galaxy. The outer layers of the shattered star, splashed into space at high speed by the explosion, now form the Crab Nebula, a name stemming from the nineteenth-century Irish astronomer Lord Rosse, who thought that its shape resembled a hermit crab.

The Crab Nebula lies between the Bull's horns, just over 1° (two Moon diameters) from Zeta (ζ) Tauri, and 6,500 light years away from Earth. Under good conditions, the Crab Nebula can be glimpsed in binoculars. For most observers, a telescope will be necessary to show its elongated misty blur, which is shaped like the flame of a candle. It measures 5 minutes of arc across, which is one-sixth the Moon's width but six times larger than the disk of Jupiter. So look for an object midway in size between the Moon and a planet. Beginners often overlook the Crab Nebula

because it is larger than they expect. It is far less spectacular in a telescope than it appears in photographs, but no observer's log is complete without a sighting of the Crab.

At the center of the Crab Nebula is one of the exceedingly small and dense objects known as neutron stars, the crushed core of the original star that exploded. A neutron star contains as much mass as the Sun, squeezed into a ball perhaps 20 km (12 miles) across. Being so small, the neutron star can spin very quickly—thirty times per second in the case of the star in the Crab. Each time it spins, the neutron star emits a flash of light, radio waves, and X-rays, like a lighthouse beam. Such a flashing neutron star is called a pulsar. At 16th magnitude, the Crab pulsar is within reach of large telescopes only.

Without supernovae, we would not be here. In a supernova, nuclear reactions convert the original hydrogen and helium into all the chemical elements of nature, which are then scattered into space, later to be collected up into new stars, planets, and perhaps life. When you look at the Crab Nebula, recall that the atoms of your own body were produced in such a way, in the supernova explosion of a star that lived and died long before the Earth was born.

Further reading

Those wishing to progress to more advanced observing will find descriptions of interesting objects for telescopes up to 200 mm aperture, along with maps of every constellation in the sky, in *Princeton Field Guide to Stars and Planets* by Ian Ridpath and Wil Tirion.

For more on the history and mythology of the constellations, see *Star Tales* by Ian Ridpath.

A complete atlas of the sky down to magnitude 6.5 is *The Cambridge Star Atlas* by Wil Tirion.

For more information, go to:

www.ianridpath.com

www.wil-tirion.com

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A user-friendly companion for stargazers of all ages, this classic beginner's guide describes all the main sights of the night sky. The newly updated book contains a chapter for each month, describing prominent stars, constellations, star clusters, nebulae, and galaxies. Readers will discover when to watch meteor showers, when eclipses will occur, and how to follow the movements of the four brightest planets (Venus, Mars, Jupiter, and Saturn).

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—Neil English, *Astronomy Now* magazine

"The star maps are first quality . . . I find them to be a pleasure to look at and use. If you have a young person or friend you would like to share your love of astronomy with, get them a pair of binoculars and this book and you'll have a stargazing friend for life."

—Mike Simonsen, *Slacker Astronomy*

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